000038

10/17/94 Michael V. Carr

Received signature pages for final document from Pat Smith.

Pat also enclosed copies of letters to Bob Dant of ARCO and to Walsh & Assoc. detailing Rico assignment as ESI in the future.

10/17/94 MVC

00000039

12/7/94 Michael V. Carr
Pat Smith called - close out files but hold on to them until ESI is assigned.

12/7/94 MVC

000040

1/16/95 Michael V. Carr
Worked on organizing & closing out files.
Gave files to Metha.

1/16/95 MVC

000160 ERB Files Andrea MacIntosh

CERCLIS FILES - LAI - Nancy 294-1195

RCRA FILES - Nick Robinson 293-1676

CDH

Glenn Mallory

CDH Files - Jo Chavez or Julie Rodriquez

WQCD - 692-3500 - wellhead protection Kathleen Reilly 692-3573

CDOW Dave Weber 291-7231

WQCD - 692-3500 Pat Nelson

WQCC - 692-3525 Marla Beiberstine

EPA Wtr Management - NPDES branch 294-1382 - Debora Griffith Files - Janet Fujita

Colo. Natl Heritage Program - Katie Pague

Durango - Ruth Carlson 247-0855 ~~Denver~~ Dove Creek - Dave Harper 677-2750

Colo. Dept. of Wildlife - Montrose - Bob Clark (303) 249-3431 fax 2957

Colo. Dept. of Natl Rscs - Dept. of Minerals & Geology

Carl Mount 866-3567 Office of Mines - Joe Nugent 880-2983

Jim Stevens - southern Colo.

BLM - Charles Fair (719) 275-0631 Montrose - District Hardrock Geologist Ben Sprouse (303) 249-7791

Denver Jim Yahnke 236-3778

B of Rec - Durango - Stan Powers (303) 385-6555

Colo. Dept. of Ntl Rscs - Water Conservation Board - Brian Hyde 866-3441 fax 4474 FIRM FEMA Maps

Colo. State Parks Natural Areas Inventory Janet Cole 866-3203 x 330

Durango Nancy McGarigal (303) 882-7296

US Forest Service - Dolores - John Reidinger (303) 882-7296 ~~Durango~~

Fish Wildlife - Lee Carlsen - Denver

Grand Junction Mike Tucker/Terry Ireland 243-2778

CDOT - Durango - Ted Vickers

Anaconda - Bob Dent

COLORADO DEPARTMENT OF HEALTH
WATER QUALITY CONTROL COMMISSION

CLASSIFICATIONS AND NUMERIC STANDARDS FOR SAN JUAN RIVER AND DOLORES RIVER BASINS 3.4.0

STATE OF COLORADO

Colorado Department of Health
4300 Cherry Creek Drive So.
Denver, CO 80222-1530

Rec'd
May 23, 1994

WQCC 2001

EPA CLOSEOUT COPY

ADOPTED:	July 13, 1982
EFFECTIVE:	August 30, 1982
AMENDED:	December 6, 1982
EFFECTIVE:	January 30, 1983
AMENDED:	December 12, 1983
EFFECTIVE:	January 30, 1984
AMENDED:	December 6, 1985
EFFECTIVE:	January 30, 1986
AMENDED:	April 7, 1986
EFFECTIVE:	May 30, 1986
AMENDED:	November 7, 1989
EFFECTIVE:	December 31, 1989
EMERGENCY AMENDMENT:	February 5, 1990
AMENDED:	June 5, 1990
EFFECTIVE:	July 31, 1990
AMENDED:	January 6, 1992
EFFECTIVE:	March 1, 1992
AMENDED:	March 1, 1993
EFFECTIVE:	April 30, 1993
AMENDED:	September 7, 1993
EFFECTIVE:	October 30, 1993

STATE OF COLORADO

WATER QUALITY CONTROL COMMISSION
''QCC-CC-B2
-300 Cherry Creek Drive South
Denver, Colorado 80222-1530
Phone: (303) 692-3520

Roy Romer
Governor
Patricia A. Nolan, MD, MPH
Executive Director

NOTICE OF FINAL ADOPTION

PURSUANT to the provisions of sections 24-4-103(5) and 24-4-103(11), C.R.S.

NOTICE IS HEREBY GIVEN that the Colorado Water Quality Control Commission, after a public hearing on September 7, 1993, and complying with the provisions of 24-4-103(3), (4) and 25-8-401(1), C.R.S., amended on September 7, 1993, pursuant to 25-8-202(1)(a), (b), and (2); 25-8-203; and 25-8-204, C.R.S., and Section 2.1.3 of the "Procedural Rules" the regulation entitled:

"Classifications and Numeric Standards for San Juan and Dolores River Basins", 3.4.0 (5 CCR 1002-8)

Providing for amendment for the water quality standard for selenium and to correct a typographical error on the silver Trout equation.

Also, pursuant to 24-4-103(8)(b), C.R.S., this amendment was submitted to the Attorney General for review and was found to be within the authority of the Water Quality Control Commission to promulgate, and further that there are no apparent constitutional deficiencies in its form or substance. Furthermore, in adopting this amendment the Commission also adopted a general Statement of Basis, Specific Statutory Authority, and Purpose in compliance with 24-4-103(4), C.R.S.

This amendment will be submitted to the Office of Legislative Legal Services within twenty (20) days after the date of the Attorney General's Opinion, pursuant to 24-4-103(8)(d), C.R.S., and to the Secretary of State in time for October 10, 1993 publication in the Colorado Register pursuant to 24-4-103(5) and (11)(d), C.R.S., and will become effective October 30, 1993.

A copy of the amended regulation is attached and made a part of this notice.*

Dated this 27th day of September, 1993, at Denver, Colorado.

WATER QUALITY CONTROL COMMISSION

Marla L. Biberstine

Marla L. Biberstine, Staff Assistant

*A copy of this regulation
is available at a charge of $5.00
pursuant to 24-4-103(9), C.R.S.

se93.fa

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3.4.0 CLASSIFICATIONS AND NUMERIC STANDARDS

SAN JUAN RIVER AND DOLORES RIVER BASINS

3.4.1 AUTHORITY

These Regulations are promulgated pursuant to C.R.S. 1973, 25-8-101 et seq., as amended, and in particular, 25-8-203 and 25-8-204.

3.4.2 PURPOSE

These regulations establish classifications and numeric standards for the San Juan and the Dolores River Basins, including all tributaries and standing bodies of water south of the northern Dolores County lines, as indicated in Section 3.4.6. The classifications identify the actual beneficial uses of the water. The numeric standards are assigned to determine the allowable concentrations of various parameters. Discharge permits will be issued by the Water Quality Control Division to comply with basic, narrative, and numeric standards and control regulations so that all discharges to waters of the State protect the classified uses. (See Section 3.1.14). It is intended that these and all other stream classifications and numeric standards be used in conjunction with and be an integral part of Regulation 3.1.0 - REGULATIONS ESTABLISHING BASIC STANDARDS AND AN ANTIDEGRADATION STANDARD AND ESTABLISHING A SYSTEM FOR CLASSIFYING STATE WATERS, AND ASSIGNING STANDARDS, AND FOR GRANTING TEMPORARY MODIFICATIONS.

3.4.3 INTRODUCTION

These Regulations and Tables present the classifications and numeric standards assigned to stream segments listed in the attached Tables (See Section 3.4.7). As additional stream segments are classified and numeric standards for designated parameters are assigned for this drainage system, they will be added to or replace the numeric standards in the Tables in Section 3.4.7. Any additions or revisions of classifications or numeric standards can be accomplished only after public hearing by the Commission and proper consideration of evidence and testimony as specified by the statute and the "basic regulations".

3.4.4 DEFINITIONS

See the Colorado Water Quality Control Act and the codified water quality regulations for definitions.

3.4.5 BASIC STANDARDS

(1) All waters of the San Juan/Dolores River Basin are subject to the following standard for temperature. (Discharges regulated by permits, which are within the permit limitations, shall not be subject to enforcement proceedings under this standard). Temperature shall maintain a normal pattern of diurnal and seasonal fluctuations with no abrupt changes and shall have no increase in temperature of a magnitude, rate, and duration deemed deleterious to the resident aquatic life. Generally, a maximum 3°C increase over a minimum of a four-hour period, lasting 13 hours maximum, is deemed acceptable for discharges fluctuating in volume or temperature. Where temperature increases cannot be maintained within this range using Best Management Practices (BMP), Best Available Technology Economically Achievable (BATEA), and Best Practical Waste Treatment Technology (BPWTT) control measures, the Commission may determine by a rulemaking hearing in accordance with the requirements of the applicable statutes and the basic regulations, whether or not a change in classification is warranted.

(2) See Basic Standards and Methodologies for Surface Water, 3.1.11 for a listing of organic standards. The column in the tables headed "Water Fish" are presumptively applied to all aquatic life class 1 streams and are applied to aquatic life class 2 streams on a case-by-case basis as shown in the tables in 3.4.6.

(3) URANIUM

(a) All waters of the San Juan/Dolores River Basin, are subject to the following basic standard for uranium, unless otherwise specified by a water quality standard applicable to a particular segment. However, discharges of uranium regulated by permits which are within these permit limitations shall not be a basis for enforcement proceedings under this basic standard.

(b) Uranium level in surface waters shall be maintained at the lowest practicable level.

(c) In no case shall uranium levels in waters assigned a water supply classification be increased by any cause attributable to municipal, industrial, or agricultural discharges so as to exceed 40 pCi/l or naturally-occurring concentrations (as determined by the State of Colorado), whichever is greater.

(d) In no case shall uranium levels in waters assigned a water supply classification be increased by a cause attributable to municipal, industrial, or agricultural discharges so as to exceed 40 pCi/l where naturally-occurring concentrations are less than 40 pCi/l.

3.4.6 TABLES

(1) Introduction

The numeric standards for various parameters in the attached tables were assigned by the Commission after a careful analysis of the data presented on actual stream conditions and on actual and potential water uses.

Numeric standards are not assigned for all parameters listed in the Tables attached to 3.1.0. If additional numeric standards are found to be needed during future periodic reviews, they can be assigned by following the proper hearing procedures.

(2) Abbreviations:

The following abbreviations are used in the attached tables:

ac	=	acute (1-day)
Ag	=	silver
Al	=	aluminum
As	=	arsenic
B	=	boron
Ba	=	barium
Be	=	beryllium
Cd	=	cadmium
ch	=	chronic (30-day)
Cl	=	chloride
Cl_2	=	residual chlorine
CN	=	free cyanide

CrIII	=	trivalent chromium
CrVI	=	hexavalent chromium
Cu	=	copper
dis	=	dissolved
D.O.	=	dissolved oxygen
F	=	fluoride
F.Coli	=	fecal coliforms
Fe	=	iron
Hg	=	mercury
mg/l	=	milligrams per liter
ml	=	milliliters
Mn	=	manganese
NH_3	=	un-ionized ammonia as N(nitrogen)
Ni	=	nickel
NO_2	=	nitrite as N (nitrogen)
NO_3	=	nitrate as N (nitrogen)
OW	=	outstanding waters
P	=	phosphorus
Pb	=	lead
S	=	sulfide as undissociated H_2S (hydrogen sulfide)
Se	=	selenium
SO_4	=	sulfate
sp	=	spawning
Tl	=	thallium
tr	=	trout
Trec	=	total recoverable
TVS	=	table value standard
U	=	uranium

ug/l	=	micrograms per liter
UP	=	use-protected
Zn	=	zinc

(3) Table Value Standards

In certain instances in the attached tables, the designation "TVS" is used to indicate that for a particular parameter a "table value standard" has been adopted. This designation refers to numerical criteria set forth in the Basic Standards and Methodologies for Surface Water. The criteria for which the TVS are applicable are on the following table.

<u>TABLE VALUE STANDARDS</u>
(Concentrations in ug/l unless noted)

PARAMETER[1]	TABLE VALUE STANDARDS [2][3]
Ammonia	Cold Water Acute = 0.43/FT/FPH/2[4] in mg/l Warm Water Acute = 0.62/FT/FPH/2[4] in mg/l
Cadmium	Acute = $e^{(1.128[\ln(hardness)]-2.905)}$ Chronic = $e^{(0.7852[\ln(hardness)]-3.490)}$ *(Trout) = $e^{(1.128[\ln(hardness)]-3.828)}$
Chromium III	Acute = $e^{(0.819[\ln(hardness)]+3.688)}$ Chronic = $e^{(0.819[\ln(hardness)]+1.561)}$
Chromium VI	Acute = 16 Chronic = 11
Copper	Acute = $e^{(0.9422[\ln(hardness)]-1.4634)}$ Chronic = $e^{(0.8545[\ln(hardness)]-1.465)}$
Lead	Acute = $e^{(1.6148[\ln(hardness)] - 2.8736)}$ Chronic = $e^{(1.417[\ln(hardness)] - 5.167)}$
Nickel	Acute = $e^{(0.76[\ln(hardness)]+3.33)}$ Chronic = $e^{(0.76[\ln(hardness)]+1.06)}$
Selenium	Acute = 135 Chronic = 17
Silver	Acute = $e^{(1.72[\ln(hardness)]-7.21)}$ Chronic = $e^{(1.72(\ln(hardness)]-9.06)}$ *(Trout) = $e^{(1.72[\ln(hardness)]-10.51)}$
Uranium	Acute = $e^{(1.102[\ln(hardness)]+2.7088)}$ Chronic = $e^{(1.102[\ln(hardness)]+2.2382)}$

TABLE VALUE STANDARDS
(Concentrations in ug/l unless noted)

PARAMETER[1]	TABLE VALUE STANDARDS [2][3]
Zinc	Acute = $e^{(0.8473[\ln(hardness)]+0.8604)}$ Chronic = $e^{(0.8473[\ln(hardness)]+0.7614)}$

TABLE VALUE STANDARDS - FOOTNOTES

(1) Metals are stated as dissolved unless otherwise specified.

(2) Hardness values to be used in equations are in mg/l as calcium carbonate. The hardness values used in calculating the appropriate metal standard should be based on the lower 95 per cent confidence limit of the mean hardness value at the periodic low flow criteria as determined from a regression analysis of site-specific data. Where insufficient site-specific data exists to define the mean hardness value at the periodic low flow criteria, representative regional data shall be used to perform the regression analysis. Where a regression analysis is not appropriate, a site-specific method should be used. In calculating a hardness value, regression analyses should not be extrapolated past the point that data exist.

(3) Both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average.

(4) $FT = 10^{.03\,(20-TCAP)}$;
TCAP less than or equal to T less than or equal to 30

$FT = 10^{.03(20-T)}$;
0 less or equal to T less than or equal to TCAP

TCAP = 20° C cold water aquatic life species present

TCAP = 25° C cold water aquatic life species absent

FPH = 1; 8 less than pH less than or equal to 9

$FPH = \frac{1 + 10^{(7.4-pH)}}{1.25}$; 6.5 less than or equal to pH less than or equal to 8

FPH means the acute pH adjustment factor; defined by the above formulas.

FT Means the acute temperature adjustment factor, defined by the above formulas.

T means temperature measured in degrees celsius.

TCAP means temperature CAP; the maximum temperature which affects the toxicity of ammonia to salmonid and non-salmonid fish groups.

NOTE: If the calculated acute value is less than the calculated chronic value, then the calculated chronic value shall be used as the acute standard.

STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

REGION: 9 BASIN: SAN JUAN RIVER Stream Segment Description	Desig	Classifications	NUMERIC STANDARDS PHYSICAL and BIOLOGICAL	INORGANIC mg/l		METALS ug/l			TEMPORARY MODIFICATIONS AND QUALIFIERS
1. Mainstem of the Navajo River and the Little Navajo River, including all tributaries, lakes and reservoirs, from the boundary of the South San Juan Wilderness Area to the San Juan-Chama diversion.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
2. Mainstem of the Navajo River from the San Juan-Chama diversion to the Colorado/New Mexico border near Edith, Colorado and from the Colorado/New Mexico border tothe confluence with the San Juan River.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ch)=50 Cd(ch)=.4 CrIII(ch)=50 CrVI(ch)=25 Cu(ch)=14	Fe(ch)=300(dis) Fe(ch)=1200 Pb(ch)=5 Mn(ch)=50(dis) Mn(ch)=1000	Hg(ch)=.05 Ni(ch)=50 Se(ch)=10 Ag(ch)=.1 Zn(ch)=50	All metals are Trec unless otherwise noted.
3. Mainstem of the Little Navajo River from the San Juan-Chama diversion to the confluence with the Navajo River; all tributaries to the Navajo River and the Little Navajo River, including all lakes and Reservoirs, from the San Juan-Chama diversions to the confluence with the San Juan River.	UP	Aq Life Warm 2 Recreation 2 Agriculture	D.O. = 5.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml						
4. All tributaries to the San Juan River, Rio Blanco, and Navajo River including all lakes and reservoirs, which are within the Weminuche Wilderness area and South San Juan Wilderness Area.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
5. Mainstem of the San Juan River and the East Fork and West Fork of the San Juan River, from the boundary of the Weminuche Wilderness Area (West Fork) and the source (East Fork) to the confluence with Fourmile Creek, including all tributaries, lakes and reservoirs except for tributaries, lakes, and reservoirs included in Segment 4.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
6. Mainstem of the San Juan River from the confluence with Fourmile Creek to Navajo Reservoir.		Aq Life Cold 1 Recreation 1 Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=100	As(ch)=50 Cd(ch)=.4 CrIII(ch)=100 CrVI(ch)=25 Cu(ch)=20	Fe(ch)=2400 Pb(ch)=10 Mn(ch)=1000 Hg(ch)=50 Ni(ch)=50	Se(ch)=20 Ag(ch)=.1 Zn(ch)=50	All metals are Trec unless otherwise noted.
7. Navajo Reservoir (portion in Colorado.		Aq Life Warm 1 Recreation 1 Water Supply Agriculture	D.O. = 5.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.5 NO_3=10 Cl=250 SO_4=250	As(ch)=50 Cd(ch)=.4 CrIII(ch)=50 CrVI(ch)=25 Cu(ch)=5	Fe(ch)=300(dis) Fe(ch)=1000 Pb(ch)=4 Mn(ch)=50(dis) Mn(ch)=1000	Hg(ch)=.05 Ni(ch)=50 Se(ch)=10 Ag(ch)=.1 Zn(ch)=50	All metals are Trec unless otherwise noted.
9. Mainstem of the Rio Blanco, including all tributaries, lakes, and reservoirs, from the boundary of South San Juan Wilderness Area to the confluence with the San Juan River, except for the specific listing in Segment 10.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch).01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
10. Mainstem of the Rito Blanco River from Echo Ditch to the confluence with the Rio Blanco River.	UP	Aq Life Cold 2 Recreation 2 Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml						

STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

REGION: 9 BASIN: SAN JUAN RIVER Stream Segment Description	Desig	Classifications	NUMERIC STANDARDS						TEMPORARY MODIFICATIONS AND QUALIFIERS
			PHYSICAL and BIOLOGICAL	INORGANIC mg/l		METALS ug/l			
11. All tributaries to the San Juan River in Archuleta County, including all lakes and reservoirs, except for specific listings in Segments 1, 4, 5, and 9.	UP	Aq Life Warm 2 Recreation 2 Agriculture	D.O. = 5.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml						

STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

REGION: 9 BASIN: PIEDRA RIVER Stream Segment Description	Desig	Classifications	NUMERIC STANDARDS PHYSICAL and BIOLOGICAL	INORGANIC mg/l		METALS ug/l			TEMPORARY MODIFICATIONS AND QUALIFIERS
1. All tributaries to the Piedra River, including all lakes and reservoirs, which are within the Weminuche Wilderness Area.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
2. Mainstem of the Piedra River, including the East and Middle Forks, from the boundary of the Weminuche Wilderness Area to the confluence with Indian Creek, except for the specific listing in Segment 3.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
3. Mainstem of the East Fork of the Piedra River from the Piedra Falls Ditch to the confluence with Pagosa Creek.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
4. Mainstem of the Piedra River from the confluence with Indian Creek to Navajo Reservoir.		Aq Life Cold 1 Recreation 1 Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=100	As(ch)=50 Cd(ch)=.4 CrIII(ch)=100 CrVI(ch)=25 Cu(ch)=16	Fe(ch)=1500 Pb(ch)=4 Mn(ch)=1000 Hg(ch)=.05 Ni(ch)=50	Se(ch)=20 Ag(ch)=.1 Zn(ch)=50	All metals are Trec unless otherwise noted.
5. All tributaries to the Piedra River, including all lakes and reservoirs, from the boundary of the Weminuche Wilderness Area to a point immediately below the confluence with Devil Creek.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
6. All tributaries to the Piedra River, including all lakes and reservoirs, from a point immediately below the confluence with Devil Creek to Navajo Reservoir, except for the specific listings in Segment 7.	UP	Aq Life Warm 2 Recreation 2 Agriculture	D.O. = 5.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml						
7. "Hatcher Lake, Stevens Lake, Pagosa Lake, Village Lake and Forest Lake."	UP	Aq Life Warm 1 Recreation 2 Water Supply Agriculture	D.O. = 5.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.06 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.25 NO_2=0.5 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac/ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac/ch)=TVS Zn(ac/ch)=TVS	

STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

REGION: 9 BASIN: LOS PINOS RIVER Stream Segment Description	Desig	Classifications	NUMERIC STANDARDS PHYSICAL and BIOLOGICAL	INORGANIC mg/l		METALS ug/l			TEMPORARY MODIFICATIONS AND QUALIFIERS
1. All tributaries to the Los Pinos River, including all lakes and reservoirs, which are within the Weminuche Wilderness Area.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
2a. Mainstem of the Los Pinos River from the boundary of the Weminuche Wilderness Area to the U.S. Hwy 160 except for the specific listing in Segment 3.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
2b. Mainstem of the Los Pinos River from U.S. Hwy 160 to the Colorado/New Mexico border.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
3. Vallecito Reservoir.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
4. All tributaries to the Los Pinos River and Vallecito Reservoir, including all lakes and reservoirs, from the boundary of the Weminuche Wilderness Area to a point immediately below the confluence with Bear Creek (T35N, R7W), except for the specific listing in Segment 5; mainstems of Beaver Creek, Ute Cr Creek, Ute Creek, and Spring Creek from their sources to their confluences with the Los Pinos River.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
5. Mainstem of Vallecito Creek from the boundary of the Weminuche Wilderness Area to Vallecito Reservoir.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=1 CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
6. All tributaries to the Los Pinos River, including all lakes and reservoirs, from a point immediately below the confluence with Bear Creek (T35N, R7W) to the Colorado/New Mexico border, except for the specific listing in Segment 4; all tributaries to the San Juan River in La Plata County.	UP	Aq Life Cold 2 Recreation 2 Agriculture	D.O. = 6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml						

STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

REGION: 9 BASIN: ANIMAS AND FLORIDA RIVER Stream Segment Description	Desig	Classifications	NUMERIC STANDARDS PHYSICAL and BIOLOGICAL	INORGANIC mg/l		METALS ug/l			TEMPORARY MODIFICATIONS AND QUALIFIERS
1. All tributaries to the Animas River and Florida River, including all lakes and reservoirs, which are within the Weminuche Wilderness Area.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.5 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
2. Mainstem of the Animas River, including all tributaries, from the source to a point immediately above the confluence with Elk Creek, except for specific listings in Segments 1 and 5 through 8a and 8b.		Recreation 2	pH = 6.5-9.0 F.Coli=2000/100ml						
3. Mainstem of the Animas River from a point immediately above the confluence with Elk Creek to the confluence with Junction Creek.	UP	Aq Life Cold 1 Recreation 2 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ch)=50 Cd(ch)=[illegible] CrIII(ch)=[illegible] CrVI(ch)=[illegible] Cu(ch)=[illegible]	Fe(ch)=300(dis) Fe(ch)=1150 Pb(ch)=43 Mn(ch)=50(dis) Mn(ch)=1000	Hg(ch)=.05 Ni(ch)=50 Se(ch)=10 Ag(ch)=.1 Zn(ch)=470	All metals are Trec unless otherwise noted.
4. Mainstem of the Animas River from the confluence with Junction Creek to the Colorado/New Mexico border.	UP	Aq Life Cold 1 Recreation 2 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ch)=[illegible] Cd(ch)=1 CrIII(ch)=[illegible] CrVI(ch)=[illegible] Cu(ch)=20	Fe(ch)=300(dis) Fe(ch)=1500 Pb(ch)=55 Mn(ch)=50(dis) Mn(ch)=1000	Hg(ch)=.05 Ni(ch)=100 Se(ch)=10 Ag(ch)=.1 Zn(ch)=150	All metals are Trec unless otherwise noted.
5. Mainstem, including all tributaries, lakes and reservoirs, of Cinnamon Creek, Grouse Creek, Picayne Gulch, Minnie Gulch, Maggie Gulch, Cunningham Creek, Boulder Creek, Whitehead Gulch, and Molas Creek from their sources to their confluences with the Animas River.		Aq Life Cold 1 Recreation 2 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
6. Mainstem of Cement Creek, including all tributaries, lakes, and reservoirs, from the source to the confluence with the Animas River.		Recreation 2	pH = 6.5-9.0 F.Coli=2000/100ml						
7. Mainstem of Mineral Creek, including all tributaries, from the source to a point immediately above the confluence with South Mineral Creek except for the specific listing in Segment 8a.		Recreation 2 Agriculture	pH = 3.5-9.0 F.Coli=2000/100ml	CN=0.2	B=0.75	As(ch)=0.1 Cd(ch)=0.005 CrIII(ch)=0.1 CrVI(ch)=0.1	Cu(ch)=0.2 Pb(ch)=0.035 Hg(ch)=0.05 Ni(ch)=0.05	Se(ch)=0.02 Ag(ch)=0.1 Zn(ch)=2.0	All metals are Trec unless otherwise noted.
8a. Mainstem of South Mineral Creek including all tributaries, lakes and reservoirs from the source to a point immediately above the confluence with Clear Creek; mainstems, including all tributaries, lakes and reservoirs of Mill Creek, and Bear Creek from sources to confluence with Mineral Creek; all lakes and reservoirs in the drainage areas described in Segments 7 through 9.		Aq Life Cold 1 Recreation 2 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
8b. Mainstem of South Mineral Creek, including all tributaries, from a point immediately above the confluence with Clear Creek to the confluence with Mineral Creek and the mainstem of Mineral Creek from immediately above the confluence with the South Fork to the confluence with the Animas River.		Aq Life Cold 1 Recreation 2 Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05	As(ch)=50 Cd(ch)=2 CrIII(ch)=100 CrVI(ch)=25 Cu(ch)=5	Fe(ch)=1000 Pb(ch)=14 Mn(ch)=1000 Hg(ch)=.05 Ni(ch)=50	Se(ch)=20 Ag(ch)=.1 Zn(ch)=50	All metals are Trec unless otherwise noted.

STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

REGION: 9 BASIN: ANIMAS AND FLORIDA RIVER Stream Segment Description	Desig	Classifications	NUMERIC STANDARDS PHYSICAL and BIOLOGICAL	INORGANIC mg/l		METALS ug/l			TEMPORARY MODIFICATIONS AND QUALIFIERS
9. Mainstem of Clear Creek from the source to the confluence with South Mineral Creek.	UP	Aq Life Cold 1 Recreation 2 Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05	As(ch)=50 Cd(ch)=.4 CrIII(ch)=100 CrVI(ch)=25 Cu(ch)=150	Fe(ch)=5000 Pb(ch)=4 Mn(ch)=1000 Hg(ch)=.05 Ni(ch)=50	Se(ch)=20 Ag(ch)=.1 Zn(ch)=480	All metals are Trec unless otherwise noted
10. Mainstem of the Florida River from the boundary of the Weminuche Wilderness Area to the Florida Farmers Canal Headgate, except for the specific listings in Segment 12b.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O.=6.0 mg/l D.O.= 7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/cu)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
11. Mainstem of the Florida River from the Florida Farmers Canal Headgate to the confluence with the Animas River.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O.(sp)=7.0 mg/l [illegible] F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
12a. All tributaries to the Animas River, including all lakes and reservoirs from a point immediately above the confluence with Elk Cr. to a point immediately below the confluence with Hermosa Cr. except for specific listings in Segment 15. All tributaries to the Florida River including all lakes and reservoirs from the source to the outlet of Lemon Reservoir except the specific listing in Segment 1. Mainstems of Red and Shearer Creeks from their sources to their confluences with the Florida River.		Aq Life Cold 1 [illegible] [illegible] [illegible]	[illegible] [illegible] [illegible] [illegible]	[illegible] [illegible] Cl_2([illegible])=0.019 Cl_2([illegible])=0.011 [illegible]	[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]	[illegible] Cd([illegible])=TVS(tr) [illegible] CrIII([illegible])=[illegible](Trec) CrVI([illegible])=TVS Cu([illegible])=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
12b. Lemon Reservoir.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10.02 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
13a. Mainstem of Junction Creek, and including all tributaries, from U.S. Forest Boundary to confluence with Animas River.	UP	Aq Life Cold 2 Recreation 2 Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05	As(ac/ch)=TVS Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec) Ni(ac/ch)=TVS Se(ac/ch)=TVS	Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
13b. All tributaries to the Animas River, including all lakes and reservoirs, from a point immediately below the confluence with Hermosa Creek to the Colorado/New Mexico border, except for the specific listings in Segments 10, 11, 12a, 12b, 13a and 14; all tributaries to the Florida River, including all lakes and reservoirs, from the outlet of Lemon Reservoir to the confluence with the Animas River, except for specific listings in Segment 12a.	UP	Aq Life Cold 2 Recreation 2 Agriculture	D.O. = 6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml						

STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

REGION: 9 BASIN: ANIMAS AND FLORIDA RIVER Stream Segment Description	Desig	Classifications	NUMERIC STANDARDS: PHYSICAL and BIOLOGICAL	INORGANIC mg/l		METALS ug/l			TEMPORARY MODIFICATIONS AND QUALIFIERS
14. Mainstem of Lightner Creek from the source to the confluence with the Animas River.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS MN(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
15. Mainstem of Purgatory Creek from source to Cascade, Cascade Creek, Soulding Creek from the source to Elbert Cree, and Nary Draw from the source to Naviland Lake.	UP	Aq Life Cold 2 Recreation 2 Water Supply Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	CN=0.2 S=0.05 NO_2=1.0	NO_3=10 Cl=250 SO_4=250	As(ch)=50 Cd(ch)=10 CrIII(ch)=50 CrVI(ch)=50	Cu(ch)=1000 Fe(ch)=0.3(dis) Pb(ch)=50 Mn(ch)=50	Hg(ch)=2 Se(ch)=10 Ag(ch)=50 Zn(ch)=5000	All metals are Trec unless otherwise noted.

STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

REGION: 9 BASIN: LA PLATA RIVER, MANCOS RIVER, McELMO CREEK, AND SAN JUAN RIVER IN MONTEZUMA COUNTY AND DOLORES COUNTY	Desig	Classifications	NUMERIC STANDARDS						TEMPORARY MODIFICATIONS AND QUALIFIERS
Stream Segment Description			PHYSICAL and BIOLOGICAL	INORGANIC mg/l		METALS ug/l			
1. Mainstem of the La Plata River, including all tributaries, lakes, and reservoirs, from the source to the Hay Gulch diversion south of Hesperus.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
2. Mainstem of the La Plata River from the Hay Gulch diversion south of Hesperus to the Colorado/New Mexico border.	UP	Aq Life Warm 2 Recreation 2 Agriculture	D.O.=5.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.1 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05	As(ch)=50 Cd(ch)=.1 CrIII(ch)=100 CrVI(ch)=25 Cu(cu)=10	Fe(ch)=1000 Pb(ch)=43 Mn(ch)=1000 Hg(ch)=.05 Ni(ch)=100	Se(ch)=20 Ag(ch)=.1 Zn(ch)=140	All metals are Trec unless otherwise noted.
3. All tributaries to the La Plata River, including all lakes and reservoirs, from the Hay Gulch diversions south of Hesperus to the Colorado/New Mexico border.	UP	Aq Life Warm 2 Recreation 2 Agriculture	D.O. = 5.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml						
4. Mainstem of the Mancos River, including all tributaries, lakes, and reservoirs, from the source of the East, West and Middle Forks to Hwy 160.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
5. Mainstem of the Mancos River from Hwy 160 to the Colorado/New Mexico border.	UP	Aq Life Warm 2 Recreation 2 Agriculture	D.O. = 5.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.01 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05	As(ch)=50 Cd(ch)=1 CrIII(ch)=100 CrVI(ch)=25 Cu(ch)=30	Fe(ch)=5100 Pb(ch)=25 Mn(ch)=1000 Hg(ch)=.05 Ni(ch)=100	Se(ch)=20 Ag(ch)=.1 Zn(ch)=150	All metals are Trec unless otherwise noted.
6. All tributaries to the Mancos River, including all lakes and reservoirs, from Hwy 160 to the Colorado/New Mexico border.	UP	Aq Life Warm 2 Recreation 2 Agriculture	D.O.=5.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml						
7. Mainstem of McElmo Creek from the source to the Colorado/Utah border.	UP	Aq Life Warm 2 Recreation 2 Agriculture	D.O. = 5.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.1 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05	As(ch)=50 Cd(ch)=5 CrIII(ch)=100 CrVI(ch)=25 Cu(ch)=19	Fe(ch)=10400 Pb(ch)=50 Mn(ch)=1000 Hg(ch)=.05 Ni(ch)=200	Se(ch)=20 Ag(ch)=.15 Zn(ch)=100	All metals are Trec unless otherwise noted.
8. All tributaries to McElmo Creek and the San Juan River in Montezuma and Dolores Counties, including all lakes and reservoirs, except for specific listings in Segments 2 through 7.	UP	Aq Life Warm 2 Recreation 2 Agriculture	D.O. = 5.0 mg/l pH=6.5-9.0 F.Coli=2000/100 ml						
9. Mainstem of the San Juan River in Montezuma County.		Aq Life Warm 1 Recreation 1 Agriculture	D.O. = 5.0 mg.l pH=6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.06 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.5	As(ac/ch)=TVS Cd(ac/ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS	Cu(ac/ch)=TVS Fe(ch)=2200(Trec) Pb)ac/ch)=TVS Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Se(ac/ch)=TVS Ag(ac/ch)=TVS Zn(ac/ch)=TVS	

STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

REGION: 9 BASIN: DOLORES RIVER Stream Segment Description	Desig	Classifications	NUMERIC STANDARDS PHYSICAL and BIOLOGICAL	INORGANIC mg/l		METALS ug/l			TEMPORARY MODIFICATIONS AND QUALIFIERS
1. All tributaries to the Dolores River and West Dolores River, including all tributaries, lakes, and reservoirs, which are within the Lizard Head Wilderness.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS MN(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
2. Mainstem of the Dolores River from the source to a point immediately above the confluence with Horse Creek.		Aq Life Cold 1 Recreation 2 Water Supply Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS $_3$(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ch=50 Cd(ch)=.4 CrIII(ch)=50 CrVI(ch)=25 Cu(ch)=6	Fe(ch)=1000 Pb(ch)=4 Mn(ch)=50(dis) Mn(ch)=1000 Hg(ch)=.05	Ni(ch)=50 Se(ch)=10 Ag(ch)=.1 Zn(ch)=100	All metals are Trec unless otherwise noted.
3. Mainstem of the Dolores River from a point immediately above the confluence with Horse Creek to a point immediately above the confluence with Bear Creek.		Aq Life Cold 1 Recreation 2 Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS $_3$(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05	As(ch=50 Cd(ch)=.4 CrIII(ch)=100 CrVI(ch)=25 Cu(ch)=14	Fe(ch)=1000 Pb(ch)=4 Mn(ch)=1000 Hg(ch)=.05 Ni(ch)=50	Se(ch)=20 Ag(ch)=.1 Zn(ch)=240	All metals are Trec unless otherwise noted.
4. Mainstem of the Dolores River from a point immediately above the confluence with Bear Creek to the bridge at Bradfield Ranch (Forest Route 505) includes McPhee Reservoir.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
5. All tributaries to the Dolores River and West Dolores River, including all lakes and reservoirs, from the source to a point immediately below the confluence with the West Dolores River except for specific listings in Segments 1 and 6 through 10; mainstem of Beaver Creek (including Plateau Creek) from the source to the confluence with the Dolores River.		Aq Life Cold 1 Recreation 2 Water Supply Agriculture	D.O. = 6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ch)=50 Cd(ch)=.4 CrIII(ch)=50 CrVI(ch)=25 Cu(ch)=5	Fe(ch)=300(dis) Fe(ch)=1000 Pb(ch)=4 Mn(ch)=50(dis) Mn(ch)=1000	Hg(ch)=.05 Ni(ch)=50 Se(ch)=10 Ag(ch)=.1 Zn(ch)=50	All metals are Trec unless otherwise noted.
6. Mainstem of the Slate Creek and Coke Over Creek, from their sources to their confluences with the Dolores River.		Aq Life Cold 1 Recreation 2 Water Supply Agriculture	D.O. = 6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ch)=50 Cd(ch)=1.1 CrIII(ch)=50 CrVI(ch)=25 Cu(ch)=17	Fe(ch)=300(dis) Fe(ch)=1000 Pb(ch)=4 Mn(ch)=50(dis) Mn(ch)=1000	Hg(ch)=.05 Ni(ch)=50 Se(ch)=10 Ag(ch)=.1 Zn(ch)=50	All metals are Trec unless otherwise noted.
7. Mainstem of Coal Creek from the source to the confluence with the Dolores River.		Aq Life Cold 1 Recreation 2 Water Supply Agriculture	D.O. = 6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
8. Mainstem of Horse Creek from the source to the confluence with the Dolores River.		Aq Life Cold 1 Recreation 2 Water Supply Agriculture	D.O. = 6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ch)=50 Cd(ch)=.4 CrIII(ch)=50 CrVI(ch)=25 Cu(ch)=22	Fe(ch)=300(dis) Fe(ch)=1000 Pb(ch)=4 Mn(ch)=50(dis) Mn(ch)=1000	Hg(ch)=.05 Ni(ch)=50 Se(ch)=10 Ag(ch)=.1 Zn(ch)=100	All metals are Trec unless otherwise noted.
9. Mainstem of Silver Creek from a point immediately below the Town of Rico's water supply diversion to the confluence with the Dolores River.	UP	Aq Life Cold 2 Recreation 2 Agriculture	D.O. = 6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05	As(ch)=50 Cd(ch)=6 CrIII(ch)=100 CrVI(ch)=25	Cu(ch)=20 Pb(ch)=16 Mn(ch)=1000 Hg(ch)=.05	Ni(ch)=50 Se(ch)=20 Ag(ch)=.1 Zn(ch)=1400	All metals are Trec unless otherwise noted.

STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

REGION: 9 BASIN: DOLORES RIVER Stream Segment Description	Desig	Classifications	NUMERIC STANDARDS: PHYSICAL and BIOLOGICAL	NUMERIC STANDARDS: INORGANIC mg/l		NUMERIC STANDARDS: METALS ug/l			TEMPORARY MODIFICATIONS AND QUALIFIERS
10. Mainstem of the West Dolores River from the source to the confluence with the Dolores River.		Aq Life Cold 1 Recreation 1 Water Supply Agriculture	D.O. = 6.0 mg/l D.O. (sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=200/100ml	NH_3(ac)=TVS NH_3(ch)=0.02 Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=250	As(ac)=50(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=300(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ch)=50(dis) Mn(ch)=1000(Trec) Hg(ch)=0.01(Trec)	Ni(ac/ch)=TVS Se(ch)=10(Trec) Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	
11. All tributaries to the Dolores River, including all lakes and reservoirs, from a point immediately below the confluence of the West Dolores River, to the bridge at Bradfield Ranch (Forest Route 505), except for the specific listing in Segment 5.	UP	Aq Life Cold 2 Recreation 2 Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH = 6.5-9.0 F.Coli=2000/100ml						

3.4.8 STATEMENT OF BASIS AND PURPOSE

I. Introduction

These stream classifications and water quality standards for State Waters of the San Juan River Basin including all tributaries and standing bodies of water and the Dolores River Basin including all tributaries and standing bodies of water south of the northern Dolores County line in all or parts of Archuleta, Conejos, Dolores, Hinsdale, La Plata, Mineral, Montezuma, Rio Grande and San Juan Counties implement requirements of the Colorado Water Quality Control Act C.R.S. 1973, 25-8-101 et seq. (Cum. Supp. 1981). They also represent the implemention of the Commission's Regulations Establishing Basic Standards and an Antidegradation Standard and Establishing a System for Classifying State Waters, for Assigning Standards, and for Granting Temporary Modifications (the "Basic Regulations")

The Basic Regulations establish a system for the classification of State Waters according to the beneficial uses for which they are suitable or are to become suitable, and for assigning specific numerical water quality standards according to such classifications. Because these stream classifications and standards implement the Basic Regulations, the statement of basis and purpose (Section 3.1.16) of those regulations must be referred to for a complete understanding of the basis and purpose of the regulations adopted herein. Therefore, Section 3.1.16 of the Basic Regulations is incorporated by reference. The focus of this statement of basis and purpose is on the scientific and technological rationale for the specific classifications and standards in the San Juan River Basin.

Public participation was a significant factor in the development of these regulations. A lengthy record was built through public hearings held on May 14, 1981. A total of 10 entities requested and were granted party status by the

Commission in accordance with C.R.S. 1973, 24-4-101 *et seq*. (Cum. Supp. 1980). A supplementary public rulemaking hearing was held September 15, 1981, restricted to those issues raised by the changes in the Act contained in Senate Bill 10 (1981). Such issues included but were not limited to: "The economic reasonableness" evaluation required by 25-8-102(5), the effect on water rights as required by 25-8-104; and the new considerations for the adoption of water quality standards required by 25-8-204 C.R.S. 1973, as amended. The record established in these hearings forms the basis for the classifications and standards adopted.

II. General Considerations

1. These regulations are not adopted as control regulations. Stream classifications and water quality standards are specifically distinguished from control regulations in the Water Quality Control Act, and they need not be adopted as control regulations pursuant to the statutory scheme.

2. The Commission has been requested in public hearings to rule on the applicability of these and other regulations to the operation of water diversion facilities, dams, transport systems, and the consequent withdrawal, impoundment, non-release and release of water for the exercise of water rights. The Commission has determined that any such broad ruling is inappropriate in the context of the present regulations. The request does not raise specific questions as to proposed classifications and standards. However, the Commission has taken into account the fact that some issues are unresolved in adopting classifications and standards. On January 5, 1981, the Commission adopted a policy statement on quality/quantity issues that addresses a number of these concerns. Finally, the Commission has adopted these regulations in compliance with the requirements of the Water Quality Control Act that have bearing on these issues (See e.g.) sections 102, 104, and 503(5).

III. Definition of Stream Segments

1. For purposes of adopting classifications and water quality standards, the streams and water bodies are identified according to river basin and specific water segments.

2. Within each river basin, specific water segments are defined, for which use classifications and numeric water quality standards, if appropriate, are adopted. These segments may constitute a specified stretch of a river mainstem, a specific tributary, a specific lake or reservoir, or a generally defined grouping of waters within the basin (e.g., a specific mainstem segment and all tributaries flowing into that mainstem segment).

3. Segments are generally defined according to the points at which the use, water quality, or other stream characteristics change significantly enough to require a change in use classification and/or water quality standards. In many cases, such transition points can be specifically identified from available data. In other cases the delineation of segments is based upon best judgments of the points where instream changes in uses, water quality, or other stream characteristics occur.

IV. Use Classifications -- Generally

1. Initially, recommendations for stream segmentation and use classifications are a result of input from 208 plans, water quality data and reports, the Division of Wildlife, and personal knowledge. After a basic outline of stream segments and use classifications was prepared, water quality data from a variety of sources was compared against the "table value" for the proposed use. "Table value" refers to the four tables attached to the "Basic Regulations". In general, if the mean plus one standard deviation ($\bar{x}$ + s) of the available data for the segment indicated that a particular parameter did not exceed the "table value" for that

recommended use, the "table value" was listed as the recommended standard for the parameter. If the $\bar{x} + s$ computation indicated that the instream concentrations of the parameter exceeded the "table value" and yet the use to be protected by that parameter was in place, then the $\bar{x} + s$ value was recommended as the standard for that parameter.

Conversely, if the ambient quality ($\bar{x} + s$) for a certain parameter exceeded the "table value" for the protection of a use, and there is information that the use is <u>not</u> in place, the use classification was modified or temporary modifications to the parameters were established. Ambient quality is generally defined as the quality attributable to natural conditions and/or uncontrollable non-point sources.

One exception to the procedure just described is for whole body contact recreation (class 1). If an active domestic waste discharge was located on the segment in question, class 1 recreation was not recommended regardless of the ambient quality, unless there was information to show that the segment was actually used for swimming. This policy was established by the WQCC in order to avoid penalizing a discharger for protecting a use which is not in place and to limit possible harm to aquatic life due to chlorine residuals.

2. The use classifications have been established in accordance with the provisions of Section 203 of the Water Quality Control Act and Section 3.1.6 and 3.1.13 of the Basic Regulations.

3. In all cases the basic regulation has been followed, in that an upstream use cannot threaten or degrade a downstream use. Accordingly, upstream segments of a stream are generally the same as, or higher in classification than, downstream segments. In a few cases, tributaries are classified at lower classifications than mainstems, where flow from tributaries does not threaten the quality of mainstem waters and where the evidence indicates that lower classification for the tributaries is appropriate.

4. There have been no "High Quality Class 1" designations assigned in this basin.

5. The Commission has determined that it has the authority to assign the classification "High Quality Waters - Class 1" and "High Quality Waters - Class 2" where the evidence indicates that the requirements of Sections 3.1.13(1)(e) of the basic regulations are met. The appropriateness of this classification has been determined on a case-by-case basis. Streams have in some cases been classified "High Quality - Class 2" for one or more of the following reasons:

   (a) to facilitate the enjoyment and use of the scenic and natural resources of the State in accordance with the Legislative Declaration of the Colorado Water Quality Control Act (25-8-102(1) C.R.S. 1973.

   (b) to provide a high degree of protection deserving of wilderness areas which are a resource providing a unique experience.

   (c) they contain threatened species or apply to wild and scenic river study areas or wilderness areas.

   (d) the concern of the USFS that High Quality 2 classification will unduly burden their management of multiple use areas is not well founded. This is because activities on Forest Service land, i.e. grazing, mineral exploration, trail and road maintenance, are considered as a historical impact upon existing ambient water quality conditions, and are non point sources which are presently not subject to any Water Quality Control Commission regulations.

   (e) a question exists as to whether existing diversion structures can be maintained consistent with a "High Quality - Class 1" designation. Because of the questions regarding authority to regulate diversions, the Class 1 designation was deemed potentially too rigid. The Commission recognizes its authority to upgrade these segments if and when it is appropriate to do so.

6. In accordance with 25-8-104, C.R.S. 1973, the Commission intends that no provision of this regulation shall be interpreted so as to supercede, abrogate, or impair rights to divert water and apply water to beneficial uses.

7. Qualifiers -- Seasonal and Intermittant

These qualifiers have been used to more fully describe characteristics of certain stream segments.

8. Recreation -- Class 1 and Class 2

In addition to the significant distinction between Recreation - Class 1 and Recreation - Class 2 as defined in Section 3.1.13(1) of the Basic Regulations, the difference between the two classifications in terms of water quality standards is the fecal coliform parameter. Recreation - Class 1 generally has a standard of 200 fecal coliform per 100 ml; Recreation - Class 2 generally has a standard of 2000 fecal coliform per 100 ml.

In accordance with the Colorado Water Quality Control Act, the Commission has decided to classify as "Recreation - Class 2" those stream segments where primary contact recreation does not exist and cannot be reasonably expected to exist in the future, regardless of water quality. The Commission has decided to classify as "Recreation - Class 1" only those stream segments where primary contact recreation actually exists, or could reasonably be expected to occur. The reasons for the application of Recreation Class 2 are as follows:

(a) The mountain streams in this region are generally unsuitable for primary contact recreation because of water temperature and stream flows.

(b) Fecal coliform is an indicator organism. Its presence does not always indicate the presence of pathogens. This depends on the source of the fecal coliform. If the source is agricultural runoff as opposed to human sewage, there may be no health hazard and therefore no significant need to reduce the presence of fecal coliform to the 200 per 100 ml. level. Also, control of nonpoint sources is very difficult.

(c) Treating sewage to meet the 200 per 100 ml. level generally means the treatment plant must heavily chlorinate its effluent to meet the limitation. The presence of chlorine in the effluent can be significantly detrimental to aquatic life. Post-treatment of effluent to meet the residual chlorine standard is expensive and often results in the addition of more chemicals which have a negative effect on water quality and can be detrimental to aquatic life. Therefore, reducing the need for chlorine is beneficial to aquatic life.

(d) Even where a treatment plant in this region might treat its effluent to attain the standard of 200 per 100 ml., agricultural runoff and irrigation return flows below the plant may result in the rapid increase of fecal coliform levels. Therefore, the benefits of further treatment are questionable.

(e) The fecal coliform standard of 2000 per 100 ml. has been established to provide general public health protection. There is no significant impact on domestic drinking water treatment plants because they provide complete disinfection. The standard of 200 per 100 ml. is not intended to protect the water supply classification.

9. Water Supply Classification

The Commission finds that Colorado is a water short state and that it is experiencing considerable growth which places additional burdens on already scarce water supplies. These considerations mitigate in favor of a conservative approach to protecting future water supplies. Where existing water quality is adequate to protect this use, and in the absence of dischargers to these segments or testimony in opposition to such classification, the water supply use has been assigned because it is reasonable to expect that it may exist in the future in such cases. For stream segments that flow through, or in the vicinity of, municipalities, this conclusion is further justified, since there is a reasonable probability that the use exists or will exist. Where the water supply classification has been opposed, the Commission has evaluated the evidence on a site specific basis, and in many cases the classification has been removed.

V. Water Quality Standards — Generally

1. The water quality standards for classified stream segments are defined as numeric values for specific water quality parameters. These numeric standards are adopted as the limits for chemical constituents and other parameters necessary to protect adequately the classified uses in all stream segments.

2. Not all of the parameters listed in the "Tables" appended to the Basic Regulations are assigned as water quality standards. This complies with Section 3.1.7(c) of the Basic Regulations.

   Numeric standards have been assigned for the full range of parameters to a number of segments where little or no data existed specific to the segment. In these cases, there was reason to believe that the classified uses were in place or could be reasonably expected, and that the ambient water quality was as good as or better than the numeric standards assigned.

3. A numeric standard for the temperature parameter has been adopted as a basic standard applicable to all waters of the region in the same manner as the basic standards in Section 3.1.11 of the Basic Regulations.

   The standard of a 3° C temperature increase above ambient water temperature as defined is generally valid based on the data regarding that temperature necessary to support an "Aquatic Life - Class 1" fishery. The standard takes into account daily and seasonal fluctuations; however, it is also recognized that the 3°C limitation as defined is only appropriate as a guideline and cannot be rigidly applied if the intention is to protect aquatic life. In winter, for example, warm water discharges may be beneficial to aquatic life. It is the intention of the Commission in adopting the standard to prevent radical temperature changes in short periods of time which are detrimental to aquatic life.

4. Numeric standards for seventeen organic parameters have been adopted as basic standards applicable to all waters of the region in the same manner as the basic standards in Section 3.1.11 of the Basic Regulations. These standards are essential to a program designed to protect the waters of the State regardless of specific use classifications because they describe the fundamental conditions that all waters must meet to be suitable for any use.

   It is the decision of the Commission to adopt these standards as basic standards because the presence of the organic parameters is not generally suspected. Also, the values assigned for these standards are not detectable using routine methodology and there is some concern regarding the potential for monitoring requirements if the standards are placed on specific streams. This concern should be alleviated by Section 3.1.14(5) of the Basic Regulations but there is uncertainty regarding the interpretation of those numbers by other entities. Regardless of these concerns, because these constituents are highly toxic, there is a need for regulating their presence in State waters. Because the Commission has determined that they have uniform applicability here, their inclusion as basic standards for the region accomplishes this purpose.

5. In many cases, the numeric water quality standards are taken from the "Tables" appended to the Basic Regulations. These table values are used where actual ambient water quality data in a segment indicates that the existing quality is substantially equivalent to, or better than, the corresponding table values. This has been done because the table values are adequate to protect the classified uses.

Consistent with the Basic Regulations, the Commission has not assumed that the table values have presumptive validity or applicability. This accounts for the extensive data in the record on ambient water quality. However, the Commission has found that the table values are generally sufficient to protect the use classifications. Therefore, they have been applied in the situations outlined in the preceeding paragraph as well as in those cases where there is insufficient data in the record to justify the establishment of different standards. The documentary evidence forming the basis for the table values is included in the record.

6. In many cases, instream ambient water quality provides the basis for the water quality standards (See 7 below). In those cases where the classified uses presently exist or have a reasonable potential to exist despite the fact that instream data reflects ambient conditions of lower water quality than the table values, instream values have been used. In these cases, the evidence indicates that instream values are adequate to protect the uses. In those cases where temporary modifications are appropriate, instream values are generally reflected in the temporary modification and table values are reflected in the corresponding water quality standard. (Goals are established for the appropriate classification affected by the parameter).

Cases in which water quality standards reflect these instream values usually involve the metal parameters. On many stream segments elevated levels of metals are present due to natural or unknown causes, as well as mine seepage from inactive or abandoned mines. These sources are difficult to identify and impractical or impossible to control. The classified aquatic life uses may be impacted and/or may have adjusted to the condition. In either case, the water quality standards are deemed sufficient to protect the uses that are present.

7. The Commission rejected the proposal to assign only "temporary" standards pending additional data collection to verify or modify values assigned. Concerned parties concurred that triennial review will lead to updating of standards as necessary. Furthermore, limited financial resources will be focused upon streams with permitted discharges.

8. In those cases where there was no data for a particular segment, or where the data consists of only a few samples for a limited range of parameters, "table values" were generally recommended. Data at the nearest downstream point was used to support this conclusion. In some cases, where the limited data indicated a problem existed, additional data was collected to expand the data base. Additionally, where there may not be existing data on present stream quality, the Commission anticipates that if necessary, additional data will be collected prior to a hearing required by C.R.S. 1973, 25-8-204(3), as amended.

9. In most cases in establishing standards based on instream ambient water quality, a calculation is made based upon the mean (average) plus one standard deviation ($\bar{x} + s$) for all sampling points on a particular stream segment. Since a standard deviation is not added to the water quality standard for purposes of determining the compliance with the standard, this is a fair method as applied to discharges.

Levels that were determined to be below the detectable limits of the sampling methodolgy employed were averaged in as zero rather than at the detectable limit. This moves the mean down but since zero is also used when calculating wasteload allocations, this method is not unfair to dischargers.

Metals present in water samples may be tied up in suspended solids when the water is present in the stream. In this form they are not "available" to fish and may not be detrimental to aquatic life. Because the data of record does not distinguish as to availability, some deviation from table values, as well as the use of $\bar{x} + s$, is further justified because it is unlikely that the total value in all samples analyzed is in available form.

A number of different statistical methodologies could have been used where ambient water quality data dictates the standards. All of them have both advantages and disadvantages. It is recognized that the $\bar{x} + s$ methodology also has weaknesses, in that the standard may not reflect natural conditions in a stream 100 per cent of the time, even though the use of $\bar{x} + s$ already allows for some seasonal variability. However the use of this methodology is nevertheless justified since it provides the most meaningful index of stream quality of all methodologies proposed for setting stream standards.

Finally, the fairness and consistency of the use of any methodology in setting standards must turn on the manner in which the standards are implemented and enforced. It is essential that there be consistency between standard setting and the manner in which attainment or non-attainment of the standards is established based on future stream monitoring data. In addition the Division must take this methodology into account in writing and enforcing discharge permits.

10. No water quality standards are set below detectable limits for any parameter, although certain parameters may not be detectable at the limit of the standards using routine methodology. However, it must be noted that stream monitoring, as opposed to effluent monitoring, is generally not the responsibility of the dischargers but of the State. Furthermore, the purpose of the standards is to protect the classified uses and some inconvenience and expense as to monitoring is therefore justifiable.

    Section 3.1.15(5) of the Basic Regulations states that "dischargers will not be required to regularly monitor for any parameters that are not identified by the Division as being of concern". Generally, there is no requirement for monitoring unless a parameter is in the effluent guidelines for the relevant industry, or is deemed to be a problem as to a specific discharge.

11. The dissolved oxygen standard is intended to apply to the epilimnion and metalimnion strata of lakes and reservoirs. Respiration by aerobic micro-organisms as organic matter is consumed is the primary cause of a natural decrease in dissolved oxygen and anaerobic conditions in the hypolimnion. Therefore, this stratum is exempt from the dissolved oxygen standard.

12. Where numeric standards are established based on historic instream water quality data at the level of $\bar{x} + s$, it is recognized by the Commission that measured instream parameter levels might exceed the standard approximately 15 percent of the time.

13. It is the Commission's intention that the Division implement and enforce all water quality standards consistent with the manner in which they have been established.

14. Hardness/Alkalinity

    Where hardness and alkalinity numbers differed, the Commission elected to use alkalinity as the controlling parameter, in order to be consistent with other river basins and because testimony from the Division staff indicated that in most cases alkalinity has a greater effect on toxic form of metals than does hardness.

VI. Water Quality Standards for Unionized Ammonia

On some Class 2 Warm Water Aquatic Life streams containing similar aquatic life communities to those found in the plains streams of the South Platte & Arkansas Basins, .1 mg/l ammonia was selected as being appropriate to protect such aquatic life.

These streams generally contain both lesser numbers and types of species than those inhabiting class 1 streams due to physical habitat characteristics, flow or irreversible water quality characteristics. The Commission felt that the incremental expense to meet a 0.06 mg/l unionized ammonia standard for present or potential discharges along these streams cannot be justified. Low flow, in these segments is often intermittent or highly impacted by diversions.

Specifically, the Commission has relaxed unionized ammonia standards to .1 mg/l or greater on such streams for the following reasons:

1. limited nature of the aquatic life present;

2. limited recreational value of species present;

3. habitat limitations, primarily flow and streambed characteristics, that impose significant limitations on the nature of aquatic life, even if ammonia reductions were attained;

4. rapid dissipation of ammonia in streams, reducing the impact of such discharges downstream; and

5. economic costs of ammonia removal, especially where such costs would fall primarily on publicly-owned treatment works, and while the availability of construction grant funds is questionable.

6. Biosurveys with support from a bioassay conducted on fathead minnows performed in the Cache la Poudre River, show that a .1 mg/l standard is appropriate to protect existing biota in that stream. The results of these studies may be reasonably extrapolated to similar plains streams; i.e., those streams that demonstrate similar chemical, physical, and biological characteristics.

Not all warmwater streams are comparable in terms of flow habitat, and types and numbers of species of aquatic life. Therefore, some variations in an appropriate ammonia standard must be tolerated, with the objective of protecting existing aquatic life. The Commission found this approach preferable to totally removing the aquatic life classsification from impacted or marginal aquatic life streams.

VII. Water Quality Standards for Uranium

Given the threat that radioactivity from uranium may pose to human health, it is advisable to limit uranium concentrations in streams to the maximum extent practicable. The Commission has adopted a standard of 40 pCi/l or natural background where higher, for the following reasons:

1. 40 pCi/l generally reflects background concentrations of uranium that may be found in streams in Colorado and therefore this amount approximates routine human exposure.

2. The statistical risk of human health hazards is small at 40 pCi/l.

3. 40 pCi/l is an interim level, established now pending the outcome of further studies currently underway.

VIII. Water Quality Standards for Cyanide

The Commission acknowledges that total cyanide is to be used in State Discharge permits until a method is authorized by EPA for measuring free cyanide, even though free cyanide is the parameter of concern. While cyanide has received special treatment in cases discussed in the segment - by - segment section which follows, a free cyanide standard based on Table Values has been established for most segments.

IX. Linkage of classifications and Standards

The Commission holds that the classifications which it adopts and the standards it assigns to them are linked. Disapproval by EPA of the standards may require reexamination by the Commission of the appropriateness of its original classification.

The reason for the linkage is that the Commission recognizes that there is a wide variability in the types of aquatic life in Colorado streams which require different levels of protection. Therefore, the numbers were chosen in some cases on a site specific basis to protect the species existing in that segment. If any reclassification is deemed a downgrading, then it will be based upon the grounds that the original classification was in error.

X. Economic Reasonableness

The Commission finds that these use classifications and water quality standards are economically reasonable. The Commission solicited and considered evidence of the economic impacts of these regulations. This evaluation necessarily involved a case-by-case consideration of such impacts, and reference is made to the fiscal impact statement for this analysis. Generally, a judgment was made as to whether the benefits in terms of improving water quality justified the costs of increased treatment. In the absence of evidence on economic impacts for a specific segment, the Commission concluded that the regulations impose no unreasonable economic burden.

XI. Classifications and Standards - Special Cases

1. Page 1, Segment 2 - San Juan River in Archuleta County (proposed as page 1, segment 2)

At issue was the recommendation contained in the Regional Water Quality Management "208" Plan that flow deficiencies and silt attributable to the San Juan - Chama diversion limited use of the segment to agriculture. Although both warm and cold water species, including trout, were observed in the segment, the Commission found from the evidence that there was perennial flow sufficient to support the aquatic life use proposed.

In view of controversy in the testimony concerning flow, the Commission considered the recommendation in the "208 Plan, yet classified the aquatic life use as class 1, cold water because other testimony indicated that recorded stream flows were ample to support aquatic life.

2. Page 2, Segment 8

This segment was incorporated into segment 5 of page 1.

3. Page 2, Segment 10

The "208" Plan was relied on by the Commission and no other evidence on this segment was presented.

4. Page 3, Segment 3 - Piedra River

The Commission retained the cold water aquatic life class 1 classification after finding that although one small portion of the segment may be intermittent, due to diversion, it quickly remakes itself and the intermittent portion is very small compared with the total length of the segment. The Commission also notes that it's decision will have no impact on any discharger.

5. Page 4, Segment 2(a) and 2(b) Los Pinos River (proposed as page 4, segment 2)

The resegmentation recommended by the Division is consistent with segmentation described in the Regional "208" Plan.

6. Page 6, Segment 2 - Animas and Florida Rivers

This is a large segment, exhibiting many water quality variables throughout its length. Although there is some evidence of insect life at points in the segment, the evidence regarding the presence of aquatic life is contradictory, and there is no evidence of fish life being present. In the absence of sufficient data to support the classification of any portion of this segment for aquatic life, the current status is being retained and no aquatic life use is assigned. The Commision expects further information to be developed through studies sponsored by the Standard Metals Corporation and the Division.

The Commission declined to assign an agricultural classification to the segment due to the absense in the record of any evidence of an agricultural use in the segment.

7. <u>Page 6, Segment 6</u>

Since Cement Creek and its tributaries are degraded by abandoned mine drainage and past discharges, the Commission did not assign aquatic and agricultural classifications to the segment as had been proposed. The segment does not currently have an aquatic life classification, and thus the status quo is maintained. The Commission placed recreation in the class 2 category as the basic use and found no agricultural use to be in place.

8. <u>Page 7, Segment 7</u>

The Woodling Study indicates that Mineral Creek from its source to its confluence with South Mineral Creek is highly toxic due to mineralization and there is not a liklihood that the sources of that toxicity will be corrected in 20 years. However the Commission concluded that there was likely to be aquatic life in that portion of Mineral Creek from below South Fork to Silverton. By changing the stream segment description such that it covers the mainstem of Mineral Creek including all tributaries from the source to a point immediately above the confluence with South Mineral Creek, the Commission was enabled to preserve the aquatic life classification on South Mineral Creek and the remaining portion of Mineral Creek into Silverton.

9. Page 8, Segment 12(a) and 12(b)
(proposed as page 6, segment 12)

Lemon Reservoir was resegmented as 12(a) for the purposes of classifying it Recreation Class 1 in recognition of known use appropriate to that classification.

10. Page 8, Segment 13(a) and 13(b)
(proposed as page 7, segment 13)

Segment 13 included Junction Creek. The Resegmentation was to separate Junction Creek as 13(a) so that different standards could be assigned to it to protect its use as a water supply for a fish hatchery. The Commission felt that the testimony supported: (a) classification of the stream for cold water aquatic life class 2 because of poor habitat and low flow conditions; and (b) assignment of numeric standards to protect the fish hatchery. The Commission felt that the use was in place and that the assignment of these standards was economically reasonable. It does not appear that discharges from trailer parks into this segment adversely impact this use. There was insufficient evidence in the record for the Commission to conclude that there would be any economic impact on such dischargers.

11. Page 8, Segment 15

Testimony was received by the Commission from the Purgatory Water and Sanitation District that the water supply classification was not applicable below the reservoir. The Commission concurred and determined that there should be no more than a class 2 aquatic life classification for this segment because of its intermitant flow and poor habitat characteristics. It was recommended that recreation class 2, agriculture and water supply be designated for the protection of the reach above the reservoir. Despite opposition to the water supply classification by Purgatory Water and Sanitation District based upon the absence of such use below Duncan Reservoir, the Commission finds that the presence of this use at other locations justifies the classification. This should not impact the District because the numeric standards for protection of the use are less stringent than those for protection of aquatic life and should be met by the discharger without additional treatment facilities.

12.. Page 11, Segment 3 - Dolores River in Dolores County

Even though the regional "208" Plan recommended that the segment be classified for a water supply use, the Commission received no testimony that there was such use in the segment. Because of high levels of manganese and the lack of evidence of in place water supply use, the Commission did not so classify the segment. Anaconda Corporation proposed numeric standards for silver and mercury. The Division recommended to the Commission that it not utilize the Anaconda proposals for those constituents because they were based on limited data, unusually high values, and questionable analytical techniques. It had not been documented that the levels of those constituents proposed by Anaconda had been routinely found in the stream. Due to this lack of certainity with respect to these metals values, the Commission did not choose to use the Anaconda data on mercury an silver.

COLORADO DEPARTMENT OF HEALTH
Water Quality Control Division
4210 E. 11th Avenue
Denver, CO 80220

FISCAL STATEMENT

Stream Classifications and Water Quality Standards for State Waters of the San Juan and Dolores River Basins including all tributaries and standing bodies of water south of the northern Dolores County line in all or parts of Archuleta, Conejos, Dolores, Hinsdale, La Plata, Mineral, Montezuma, Rio Grande, and San Juan Counties.

I. INTRODUCTION

The Water Quality Control Commission is charged with the responsibility to conserve, protect, and improve the quality of state waters pursuant to C.R.S. 1973, 25-8-101 *et seq*.

The Commission is further empowered and directed to classify waters of the State and to promulgate water quality standards for any measurable characteristic of the water in order to protect both the uses in place and those that can be reasonably expected in the future. (25-8-203 and 25-8-204) The above-titled document assigns use classifications and standards for the state waters in the listed areas in accordance with the "basic regulations" adopted May 22, 1979.

The measurable fiscal impacts which may be caused by these regulations are as follows:

- Cost of construction due to requirements for increased levels of treatment by municipal waste treatment facilities;

- Cost of construction due to requirements for increased levels of treatment by industrial/commercial waste treatment facilities;

- Cost of Operation and Maintenance associated with increased levels of treatment required of municipalities;

- Cost of instream monitoring and laboratory analysis for new parameters added by the standards.

Dischargers will not be required by the adoption of these regulations to do stream monitoring. The state, federal and local agencies now doing instream monitoring will have some increased cost; however, any additional frequency should be done to improve state surveillance and would be needed regardless of standard changes.

The stream classifications and standards adopted by the Commission will protect the water uses primarily through control of point source pollution. Non-point source pollution will be controlled primarily through management practices which are in existence or which will be implemented in the future. Future management practices need careful consideration and may be the result of 208 area-wide wastewater management plans developed by regional planning agencies and being updated annually. These plans involve local governments with general assistance from state government. Some of the possible non-point source pollution may be controlled through "Control Regulations" yet to be promulgated by the Commission. These types of controls could involve runoff from construction, mining activites, and urban areas. It is not certain what controls are needed at this time and there is no way that possible costs can be identified at this time.

Persons who benefit from standards which will protect existing and future anticipated uses can be identified as all persons benefiting from recreation, municipal water supply, and agriculture. These benefits are directly economic for agriculture, industry, and municipalities whose health benefit costs are reduced by having clean water, and are both economic and non-quantifiable for some uses such as fishing, recreation, and the aesthetic value of clean waters. Furthermore, benefits will result from human health protection and lack of debilitating disease. Figures have been developed for a recreation/fishing day which can be applied to that aspect of a water use; however, figures which have been developed for total recreation/fishing day uses have been developed statewide and could not be applied region-by-region or stream-by-stream.

The uses of water in this region are adequately protected by these standards. Most municipal treatment facilities and industrial facilities are currently adequate, or are already being upgraded, in order to meet previous requirements. Any additonal facilities or expansions in this region will generally be caused by increased capacity required because of population growths or industrial enlargement. Industries are required by federal statute to meet effluent limitations described as "Best Available Technology Economically Achievable" (BATEA) by 1983 or 1984. For most major industries in this region, the water quality standards should not require treatment beyond these limitations.

The fiscal impact of any regulatory decision must take into account only the incremental costs explicitly associated with the regulations as finally promulgated. Costs and expenditures associated with the status quo, regulations of other regulatory agencies, or regulations already in effect should not be included in an assessment of the fiscal impact of the San Juan and Dolores River Basins classifications.

In addition, a distinction must be made between actual expenditures or dislocations that will be immediately or unavoidably necessary upon promulgation of these classifications and standards, and those costs which are speculative in nature. In keeping with concepts of 'Expected Value', it is proper for the Commission to place more emphasis on definite impacts.

With the passage in 1981 of Senate Bill 10, amending the Colorado Water Quality Control Act, it became incumbent upon the Water Quality Control Commission to consider the economic impact of their decisions with more emphasis placed upon the concept of the "Economic Reasonableness". Supplementary hearings were held by the Commission on the San Juan and Dolores River Basins to consider the new provisions of the Act. Charged with such a mandate, the Commission was quite sensitive to the objective of minimizing the socio-economic "price" of clean water while adhering to the anti-degradation policy that water quality be preserved and protected in all cases, and improved wherever feasible.

The analysis and data which follow are derived primarily from testimony and exhibits offered by interested parties during the course of the rulemaking hearings. This was supplemented by staff assessments of potential impacts upon other major entities who were not formally represented. The impacts are separately presented for the public and private sectors. No attempt has been made to identify future development costs as this type of data is not readily available and estimation techniques are dependent upon many highly subjective assumptions.

II. FISCAL IMPACT: PUBLIC SECTOR

The primary fiscal impact upon the public sector in these basins involves the potential for increased domestic wastewater treatment costs associated with the stream classifications and water quality standards. Other costs, such as tax and employment base impacts due to forgone industrial development opportunities or mitigated growth potentials, can be theoretically postulated but are difficult to quantify. Generally, it is recognized that higher tap fees, service charges or property taxes associated with increased treatment costs can potentially affect industrial and residential siting decisions. While the Commission acknowledges the existence of such potentials, the lack of firm evidence and actual tax base impact estimates make deliberative assessment impractical.

In these basins the Commission acknowledged five municipalities that could be potentially impacted: Durango, Forest Lake, Bayfield, Ignacio, and the Purgatoire Water and Sanitation District. In each case, the ammonia standard was the controlling factor. Additional data led to the conclusion that Durango should not need to go beyond secondary treatment.

Low flow in the Pinos River and/or increased treatment flows could cause an ammonia impact upon Forest Lake, Bayfield and Ignacio. Currently, secondary treatment is all that is required of these municipalities under existing permits. None of these entities presented testimony that indicated an immediate or impending impact due to ammonia requirements so the actual fiscal impact, if any, cannot be properly assessed.

The Purgatoire Water and Sanitation District presented testimony indicating the necessity of tertiary treatment (AWT) at a cost of $480,000 if the stream were classified as proposed with an Aquatic Class One designation. This designation was not adopted so it is believed that Purgatoire will not incur a cost as a result of these classifications and standards.

III. FISCAL IMPACT: PRIVATE SECTOR

Several entities presented testimony regarding water rights issues but there was no firm evidence indicating any specific water rights impacts and no cost estimates were provided. These basins have a sparse industrial/commercial density and it is believed that these regulations will have a minimal impact upon the private sector.

While metals standards could impose an impact upon unidentified entities, it is impossible to identify who they might be and to what extent they might be impacted. In any event, any active operation is already covered by permit and, in lieu of specific testimony, it must be assumed that no recognizable impacts will result from these classifications and standards.

In recognition of the benefits to be derived from protecting aquatic life and public water supply and that no immediate fiscal impacts will result from this regulation, it is concluded that the Commission acted in an economically responsible and reasonable manner.

PARTIES TO THE SAN JUAN RIVER AND DOLORES RIVER BASINS

1. Anaconda Copper Company
2. Purgatory Water and Sanitation District
3. Climax Molybdenum
4. Pagosa Area Water and Sanitation District
5. Golf Host West, Inc.
6. Eaton International Corp.
7. City of Durango
8. Trout Unlimited
9. Daniel McCarthy
10. Chevron Resources, Inc.

STATEMENT OF BASIS AND PURPOSE REGARDING THE ADOPTION OF NON-SUBSTANTIVE CORRECTIONS TO THE CLASSIFICATIONS AND NUMERIC STANDARDS FOR THE ARKANSAS, SAN JUAN AND DOLORES, RIO GRANDE AND SOUTH PLATTE RIVER BASINS.

In accordance with the requirements of 24-4-103(4), C.R.S. 1973, the Commission makes these findings and adopts this Statement of Basis and Purpose.

The Commission at a public rulemaking hearing November 8, 1982, adopted clerical and editorial corrections to the Commission's current regulations numbered respectively 3.2.0, 3.4.0, 3.6.0, and 3.8.0. These regulations are contained in Article 3, Water Quality Standards, of the Policies, Regulations, and Guidelines of the Water Quality Control Commission. (5CCR 1002-8)

In adopting these corrections the Commission considered the economic reasonableness of its action, except as specified the corrections in no way change the classifications and numeric standards originally adopted by the Commission. Other than written comment from the City of Westminster no testimony was offered at the public hearing.

The consolidated changes adopted by the Commission are included in this Basis and Purpose for information. The Secretary of State was provided corrected pages for each of the regulations as replacements for the regulations previously published.

Dated this 8th day of November, 1982 at Denver, Colorado.

FISCAL STATEMENT

Regarding The Adoption of Non-Substantive Corrections To The Classifications And Numeric Standards For The Arkansas, San Juan and Dolores, Rio Grande and South Platte River Basins.

The Water Quality Control Commission found that clerical and editorial corrections to the Commission's current regulations numbered respectively 3.2.0, 3.4.0, 3.6.0, and 3.8.0 have no fiscal impact.

Dated this 8th day of November, 1982 at Denver, Colorado.

3.4.9 STATEMENT OF BASIS, SPECIFIC STATUTORY AUTHORITY, AND PURPOSE:

The provisions of 25-8-202(1)(a)(b) and (2); and 25-8-204 C.R.S. provide the specific statutory authority for the numeric standards that were adopted.

The Commission also adopted in compliance with 24-4-103(4) C.R.S. the following statements of basis and purpose and fiscal impact.

BASIS AND PURPOSE - SAN JUAN AND DOLORES RIVER BASINS

The basis and purpose for the changes by segment is as follows:

Segment 6, Piedra River - This segment contains the lakes listed for inclusion in the proposed Segment 7. In order to separate these lakes from this segment, the description must be changed.

Segment 7, Piedra River - The lakes listed are all fisheries and a majority of them are used for sport fishing. Their present inclusion in Segment 6 does not represent their actual use, i.e., Class 1 Aquatic Life, or provide standards to protect this use. The Commission has classified all reservoirs in Segment 7 as Warm Water Class 1 instead of Cold Water Class 1 on the basis that: 1) all reservoirs are already heavily managed, including aeration; 2) trout have been introduced into the reservoirs and do not occur naturally; and 3) at least temperature excursions above that require for cold water classification occur.

The Commission notes that the data base supporting this change in classification to warm water Class 1 is not extensive and further water quality monitoring is encouraged.

Segment 15, Animas River - Studies conducted by the Water Quality Control Division indicate that both Goulding Creek and Nary Draw are intermittent streams more appropriately classified under Segment 15 than under Segment 12a. The change in the description of Segment 15 will accomplish this and provide adequate protection of the uses.

Adopted: December 6, 1985
Effective: January 30, 1986

<u>Segment 8, La Plata River, Mancos River, McElmo Creek, and San Juan River</u>	- The change in description to include Dolores County will include those streams which are unclassified under the existing description.
<u>Change in basin description at top of pages 9 and 10 of the Tables</u>	- Change is needed to accurately reflect the streams included in this section with the change in description of Segment 8.

FISCAL IMPACT STATEMENT - SAN JUAN AND DOLORES RIVER BASINS

As these changes are in response to an increasing body of knowledge concerning accurate classifications of uses and the standards necessary to maintain those uses, they are not economically driven. The only discharger in the basins, Pagosa Area Water & Sanitation District, is moving their discharge from Pagosa Lakes and will not be adversely harmed by these standards. Recognition of higher classifications and inclusion of new classifications are benefits in light of the goals of the Water Quality Control Act and these regulations will serve to maintain and enhance those uses. Recognition of intermittent streams and subsequent Class 2 designations will have the potential of decreased treatment costs if development occurs near them in the future. As no adverse economic impact is anticipated by these regulations, and because they more accurately protect existing and potential beneficial uses, the Commission regards these changes as economically reasonable.

Adopted: December 6, 1985
Effective: January 30, 1986

3.4.10 BASIS AND PURPOSE:

At the triennial review of the San Juan and Dolores River Basins in May, 1985, the Water Quality Control Division pointed out that the Division had recently (April, 1985) granted a variance to the limitation for cadmium in Anaconda Company's Rizo Mine discharge permit. The underlying stream concentration which was used to support the variance was 0.002 mg/l, and was based upon an $\bar{x}$ + s calculation of fifteen cadmium data points above the St. Louis ponds discharge collected in 1981. The rationale for the variance anticipated the establishment of a revised cadmium standard through the established standards setting procedure of the Water Quality Control Commission, and noted that subsequent to that procedure, an amended discharge limitation in Anaconda's discharge permit would be written.

This amendment initiates the standards setting process envisioned when the cadmium variance was granted to Anaconda with the expectation that the variance will expire upon adoption of a new standard.

The revision of the cadmium standard from 0.0004 mg/l to 0.0012 mg/l is based upon a review of data supplied by Anaconda at stations D2 and D3 above the discharge point on the Dolores River. Consideration was also given to the existing table value for cadmium at the ambient hardness levels in the river, and the draft position on cadmium is being considered by the Basic Standards Task Force.

FISCAL IMPACT STATEMENT:

The costs of attaining a cadmium stream standard fall to the Anaconda Company at the present time since they are the sole point source discharger to the segment. A new treatment system was installed at the St. Louis pond site in February, 1984, and appears capable of producing an effluent of high enough quality to protect the stream standard during all flow seasons.

Other sources of cadmium enter the segment below Anaconda's discharge and account for a greater portion of mass loading to the segment than the permitted discharge. These sources are all classed as nonpoint and include mineralized groundwater, drainage from abandoned mines, and runoff through tailings. It is conceivable that costs for cadmium loading reduction could accrue to owners of these sources at such time that a nonpoint source control program were implemented. The necessary investment to meet the proposed standard has already been made by Anaconda and that portion of the costs attributable to cadmium removal cannot be measured since all metals will be reduced by the method of treatment used.

Benefits to attaining the amended standard accrue to all users of the stream and also to Anaconda in the form of relaxed discharge limitations over those based on the 0.0004 mg/l standard. The amended standard should protect the uses of the stream as fully as possible since it is no less stringent than the upstream ambient quality and is compatible with the elevated hardness levels found in the river at low flows.

3.4.11 STATEMENT OF BASIS, SPECIFIC STATUTORY AUTHORITY, AND PURPOSE; AUGUST, 1989 HEARING ON MULTIPLE SEGMENTS

The provisions of 25-8-202(1)(a), (b) and (2); 25-8-203; 25-8-204; 25-8-207 and 25-8-402 C.R.S. provide the specific statutory authority for adoption of these regulatory amendments. The Commission also adopted, in compliance with 24-4-103(4), C.R.S., the following statement of basis and purpose.

BASIS AND PURPOSE:

First, the Commission has adopted new introductory language for the tables, in section 3.4.6(2). The purpose of this language is to explain the new references to "table value standards" (TVS) that are contained in the Tables. The other changes considered and adopted are addressed below.

A. Jurisdiction on Tribal Lands

On the issue of classifying and setting standards on tribal lands, the Commission was advised to classify and set standards as they would for waters on non-tribal lands with the understanding that the Commission is not attempting to assert jurisdiction or to usurp the authority of the tribe to classify and set standards for waters within the boundaries of the reservation.

B. Table Value Standards for Metals

> San Juan, Segment 7; Los Pinos, Segment 4; Animas, Segment 5; Dolores, Segments 5 and 7.

Numerical standards for metals for these segments have in most instances previously been based on table values contained in Table III of the Basic Standards and Methodologies for Surface Water. Table III has been substantially revised, effective September 30, 1988. A few of these segments had no new data to indicate that new table value standards are not appropriate. There are also some of these segments whose previous standards were based in part on ambient quality, since their quality did not meet old table values based on alkalinity ranges. However, these segments generally have much higher hardness than alkalinity, and the new table values (based on hardness-dependent equations) are now appropriate as standards.

C. New High Quality 2 Designations

> San Juan, Segments 1, 5, and 9; Piedra, Segments 3 and 5; Los Pinos, Segment 2a; Animas, Segments 8a, 10, 11, 12a, 12b, and 14; La Plata, Segments 1 and 4; Dolores, Segments 4 and 10.

From the information available, it appears that the existing quality of these segments meets or exceeds the quality specified by the revised criteria in Table III, and new acute and chronic table value standards based thereon have therefore been adopted.

Second, in addition to these standards changes, the use classifications have been revised where necessary so that each of these segments has the following classifications:

Recreation - Class 1

Cold Water Aquatic Life - Class 1

Water Supply

Agriculture

D. <u>Existing High Quality 2 Segments; New Classifications and Standards</u>

San Juan, Segment 4; Piedra, Segments 1 and 2; Los Pinos, Segment 1; Animas and Florida, Segment 1; Dolores, Segment 1.

These segments were already described as High Quality Class 2, as all are wilderness and wild and scenic rivers. Available information indicates that the parallel new High Quality 2 designation continues to be appropriate for each, along with new table value numeric standards and equations for cold water aquatic life classifications, i.e., acute (trout) for cadmium and zinc and chronic (trout) for silver.

The following use classifications, and associated table value standards, have been adopted for these segments:

Recreation - Class 1

Cold Water Aquatic Life - Class 1

Water Supply

Agriculture

E. <u>New Use-Protected Designations; No Change in Numeric Standards</u>

San Juan, Segments 3, 10, and 11; Piedra, Segment 6; Los Pinos, Segment 6; Animas and Florida, Segments 3, 4, 9, 13b, and 15; La Plata, Mancos, McElmo, and San Juan, Segments 2, 3, 5, 6, 7, and 8; Dolores, Segments 9 and 11.

These segments all qualify for a Use-Protected designation based either on their present classifications or the existing standards contain three or more of the following metals parameters whose concentrations, based on total recoverable metals, indicate they may be worse than that specified in Table III for the protection of aquatic life class 1 use: cadmium, copper, iron, lead, or zinc.

F. New Use-Protected Designation; Table Value Standards

Piedra, Segment 7; Animas and Florida, Segment 13a.

These segments qualify for a Use-Protected designation based upon their classification. Previous standards were based on table values and no new data was presented to indicate new table value standards are not appropriate.

For these segments, acute and chronic table value standards have been adopted for arsenic, cadmium, chromium (III and IV), copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc.

G. Revised Recreation Classification

San Juan, Segments 2 and 6; Piedra, Segment 4; Los Pinos, Segment 2b; La Plata, Segment 9

The recreation classification on these segments has been upgraded from Class 2 to Class 1 (whole body immersion is likely) because the stream sampling data indicate that the fecal coliform standard 200/100 ml is not being exceeded, and conditions are normally considered suitable for swimming or intentional whole body contact. This action was taken in response to a concern raised by the EPA regarding segments not attaining "fishable/swimmable" uses.

H. Other Revisions

1. Los Pinos, Segments 3 and 5.

Based on stream sampling data for Segment 3, table value standards were established as were ambient standards for cadmium and lead. For Segment 5, ambient standards for cadmium and lead were added; table value standards were added for the remaining metals.

2. San Juan, Segment 9 (Four Corners Area)

Table Value Standards for metals have been adopted for this segment with the exception of total recoverable iron whose 50 percentile value is 2200 ug/l. In addition, the recreation classification has been changed from Class 2 to Class 1 with a fecal coliform standard of 200/100 ml.

0486m/0025m/
10/89 Rev.

PARTY STATUS LIST
OF
PUBLIC RULEMAKING HEARING
AUGUST 7, 1989

For consideration of adoption of amendments to the regulations for the San Juan River Basin, 3.4.0 (5 CCR 1002-8)

NAME	REPRESENTED BY	MAILING ADDRESS	TELEPHONE
1. The Southwestern Water Conservation District, "District"	Richard L. Sisk	Maynes, Bradford & Shipps P.O. Box 2717 1060 Main Avenue, Suite 103 Durango, Colorado 81302-2717	303-247-1755
2. The San Juan County Mining Venture	William C. Robb	Welborn, Dufford, Brown & Tooley, P.C. Suite 1700 1700 Broadway Denver, Colorado 80290-1701	303-861-8013
3. The Pagosa Area Water and Sanitation District, "District"	James P. Collins	Collins & Cockrel, P.C. 390 Union Blvd. Lakewood, Colorado 80228	303-986-1551
	Timothy J. Beaton	1507 Pine Street Boulder, Colorado 80302	303-447-0028

0332m/0023m

3.4.12 STATEMENT OF BASIS, SPECIFIC STATUTORY AUTHORITY, AND PURPOSE; FEBRUARY, 1990 EMERGENCY RULEMAKING HEARING

The provisions of 25-8-208 and 25-8-402 (5) C.R.S. provide the specific statutory authority for action on these regulatory amendments

BASIS AND PURPOSE:

The Commission held this emergency rulemaking hearing to readopt the classifications and numeric standards for the San Juan River and Dolores River Basins to correct errors in the original filing. The affected regulation was amended on November 7, 1989 and was filed within the required timeframes with the Secretary of State's Office and the Office of Legislative Legal Services. The Commission learned shortly after the filings that three (3) pages had been inadvertently left out of the regulation, and that a typographical error appeared throughout the classification and standards tables that are part of the regulation. The Commission office was able to correct the errors with a replacement filing with the Secretary of State's Office so that the regulation published in the CCR (Colorado Code of Regulation) correctly reflects the Commission's actions.

The Office of Legislative Legal Services notified the Commission that it could not accept the corrected materials as they had not been submitted within the 20 day timeframe called for in section 24-4-103 (8) (d), C.R.S. of the "State Administrative Procedure Act". It was suggested that the Commission needed to repromulgate the rules that contained the errors submitted in November, 1989 and resubmit them.

The Commission elected to proceed on an emergency rulemaking basis to avoid any confusion that could result due to the fact that the two filings are currently not the same. Therefore, the Commission adopted the corrected version of the regulation at an emergency rulemaking hearing on February 6, 1990. Final action on the readoption is scheduled for June 5, 1990.

1776m/0184m/cmc

3.4.12 STATEMENT OF BASIS, SPECIFIC STATUTORY AUTHORITY, AND PURPOSE; JUNE, 1990 RULEMAKING HEARING

The provisions of 25-8-202(1)(a), (b) and (2); 25-8-203; 25-8-204; 25-8-207 and 25-8-402 C.R.S. provide the specific statutory authority for action on these regulatory amendments.

BASIS AND PURPOSE:

The Commission held this rulemaking hearing to make permanant the emergency hearing that was held in February, 1990 to readopt the classifications and numeric standards for the San Juan River and Dolores River Basins to correct errors in the original filing. The affected regulation was amended on November 7, 1989 and was filed within the required timeframes with the Secretary of State's Office and the Office of Legislative Legal Services. The Commission learned shortly after the filings that three (3) pages had been inadvertently left out of the regulation, and that a typographical error appeared throughout the classification and standards tables that are part of the regulation. The Commission office was able to correct the errors with a replacement filing with the Secretary of State's Office so that the regulation published in the CCR (Colorado Code of Regulation) correctly reflects the Commission's actions.

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1776m/0184m/cmc

3.4.13 STATEMENT OF BASIS, SPECIFIC STATUTORY AUTHORITY AND PURPOSE; MARCH 1, 1993 HEARING:

The provisions of 25-8-202(1)(a), (b) and (2); 25-8-203; 25-8-204; and 25-8-402 C.R.S. provide the specific statutory authority for adoption of these regulatory amendments. The Commission also adopted in compliance with 24-4-103(4), C.R.S., the following statement of basis and purpose.

BASIS AND PURPOSE:

The changes to the designation column eliminating the old High Quality 1 and 2 (HQ1, HQ2) designations, and replacing HQ1 with Outstanding Waters (OW) designation were made to reflect the new mandates of section 25-8-209 of the Colorado Water Quality Act which was amended by HB 92-1200. The Commission believes that the immediate adoption of these changes and the proposals contained in the hearing notice is preferable to the alternative of waiting to adopt them in the individual basin hearings over the next three years. Adoption now should remove any potential for misinterpretation of the classifications and standards in the interim.

In addition, the Commission made the following minor revisions to all basin segments to conform them to the most recent regulatory changes:

1. The glossary of abbreviations and symbols were out of date and have been replaced by an updated version in section 3.4.6(2).

2. The organic standards in the Basic Standards were amended in October, 1991, which was subsequent to the basin hearings. The existing table was based on pre-1991 organic standards and are out of date and no longer relevant. Deleting the existing table and referencing the Basic Standards will eliminate any confusion as to which standards are applicable.

3. The table value for ammonia and zinc in the Basic Standards was revised in October, 1991. The change to the latest table value will bring a consistency between the tables in the basin standards and Basic Standards.

4. The addition of acute un-ionized ammonia is meant to bring a consistency with all other standards that have both the acute and chronic values listed. The change in the chlorine standard is based on the adoption of new acute and chronic chlorine criteria in the Basic Standards in October, 1991.

Finally, the Commission confirms that in no case will any of the minor update changes described above change or override any segment-specific water quality standards.

3.4.14 STATEMENT OF BASIS, SPECIFIC STATUTORY AUTHORITY AND PURPOSE, SEPTEMBER 7, 1993:

The provisions of 25-8-202(1)(a), (b) and (2); 25-8-203; 25-8-204; and 25-8-402 C.R.S. provide the specific statutory authority for adoption of these regulatory amendments. The Commission also adopted in compliance with 24-4-103(4), C.R.S., the following statement of basis and purpose.

BASIS AND PURPOSE:

On November 30, 1991, revisions to "The Basic Standards and Methodologies for Surface Water",. 3.1.0 (5 CCR 1002-8), became effective. As part of the revisions, the averaging period for the selenium criterion to be applied as a standard to a drinking water supply classification was changed from a 1-day to a 30-day duration. The site-specific standards for selenium on drinking water supply segments were to be changed at the time of rulemaking for the particular basin. Only one river basin, the South Platte, has gone through basin-wide rulemaking since these revisions to the "Basic Standards". Through an oversight, the selenium standards was not addressed in the rulemaking for this basin and has since become an issue in a wasteload allocation being developed for segments 15 and 16 of the South Platte. Agreement on the wasteloads for selenium is dependent upon a 30-day averaging period for selenium limits in the effected parties permits. Therefore, the parties requested that a rulemaking hearing be held for the South Platte Basin to address changing the designation of the 10 ug/l selenium standard on all water supply segments from a 1-day to a 30-day standard. The Water Quality Control Division, foreseeing the possibility of a selenium issue arising elsewhere in the state, made a counter proposal to have one hearing to change the designation for the selenium standard on all water supply segments statewide. The Commission and the parties concerned with South Platte segments 15 and 16 agreed that this would be the most judicious way to address the issue.

The change in the averaging period may cause a slight increase in selenium loads to those segments which have CPDS permits regulating selenium on the basis of a water supply standard. However, these segments are only five in number and the use will still be fully protected on the basis that the selenium criterion is based on 1975 national interim primary drinking water regulations which assumed selenium to be a potential carcinogen. It has since been categorized as a non-carcinogen and new national primary drinking water regulations were promulgated in 1991 that raised the standard to 50 ug/l.

The Commission also corrected a type error in the TVS for Silver by changing the sign on the exponent for the chronic standard for Trout from + 10.51 to - 10.51.

1H

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

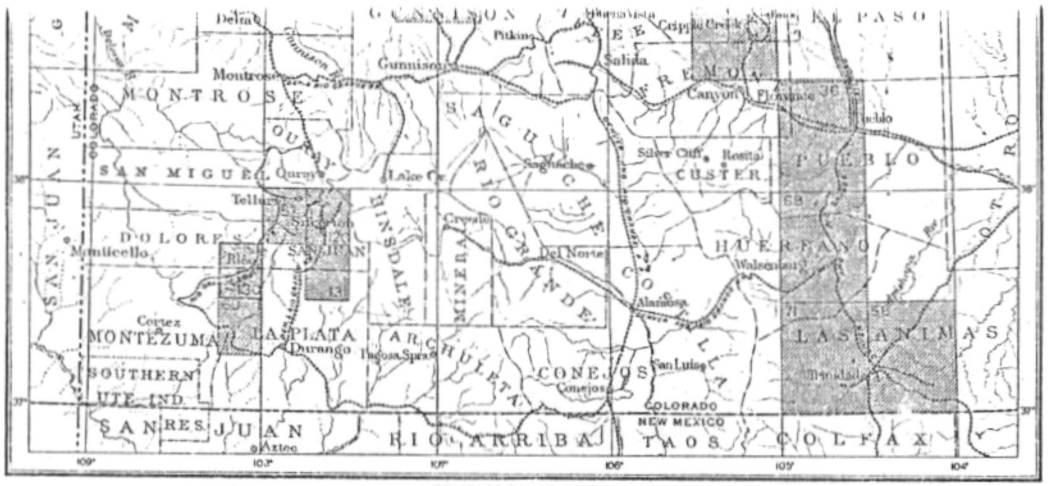
OF THE

UNITED STATES

RICO FOLIO

COLORADO

INDEX MAP



SCALE: 40 MILES=1 INCH

RICO FOLIO

OTHER PUBLISHED FOLIOS

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FOLIO 130

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS. S. J. KUBEL, CHIEF ENGRAVER
1905

DESCRIPTION OF THE RICO

By Whitman Cross and F. L. Ransome.

GEOGRAPHY AND GENERAL GEOLOGY OF

By Whitman Cross.

INTRODUCTION.

The Rico quadrangle is situated in southwestern Colorado, about 50 miles west of the Continental Divide, in the zone bordering the San Juan Mountains, almost at the head of the Dolores River. It is bounded by meridians 108° and 108° 15' west longitude and parallels 37° 30' and 37° 45' north latitude, embracing about 236 square miles.

GENERAL RELATIONS OF THE QUADRANGLE.

Relations to the plateau country.—The Rico quadrangle lies in the north-south zone that marks the eastern border of a very notable plateau surface which covers the greater part of the area between the Colorado River in Utah and the San Juan Mountains of Colorado. Below the gently undulating surface of this plateau many canyons have been carved by streams, one of the principal gorges being that of the Dolores River. Entering its canyon valley within the Rico quadrangle this stream flows with irregular course for about 18 miles in a southwesterly direction and then swings to a general north-northwest trend, which it maintains for over 100 miles to the Grand River.

The larger part of the plateau surface lying between the Dolores and Colorado rivers is called the Great Sage Plain, while its direct continuation eastward and toward the head of the Dolores is named the Dolores Plateau.

This broad plain surface is due chiefly to a heavy sandstone, the Dakota (Cretaceous), and its undulations are in part structural, in harmony with the slightly varying dips of the sandstone, and in part owing to remnants of the soft, thick shale formation normally overlying the sandstone. The Great Sage Plain of Utah has a general elevation of 6000 to 7000 feet above the sea. Eastward the Dolores Plateau gradually rises with the dip of the sandstone until, on the western border of the Rico quadrangle, it has an altitude of over 9000 feet. Beyond that line it rises more rapidly as the Dakota sandstone and other formations take part in the local structures of the Rico and La Plata Mountains, to be described in detail.

Relations to the San Juan Mountains.—The southwestern front of the volcanic San Juan Mountains lies 6 to 8 miles northeast of the Rico quadrangle. The intervening space is characterized by irregular foothill topography, with features due in part to the upturning and erosion of various sedimentary formations about the ancient San Juan center of uplift and in part to large masses of intrusive igneous rocks. These intrusions are similar in character to those of the Rico Mountains.

No surface volcanic rocks of the San Juan succession occur in the Rico quadrangle. It is probable, however, that the San Juan volcanics once extended over this area and have been removed by erosion. In support of this idea may be mentioned the fact that only a few miles north of the Rico area, on the south slopes of the San Miguel Mountains, a line of high peaks which are geologically as well as topographically western outliers of the San Juan Mountains, remnants of the horizontal

Features of the Rico Mountains.—The small group of mountains in the northeastern section of the quadrangle is in large degree a local center of uplift which is apparently independent of igneous intrusion; but it is also to an important extent characterized by many injected laccolithic masses. The intrusive rocks are of kinds common in the so-called laccolithic mountain groups of the plateau country, embracing the La Plata, El Late, Carriso, Abajo, La Sal, and Henry mountains, most of which are plainly visible from the Rico summits. This character of the Rico group was not recognized during the Hayden Survey.

The sedimentary section.—In general the section of sedimentary formations exposed in the valley of the Dolores River is that normal to the zone about the San Juan Mountains. It is, for example, like that shown in the adjoining Telluride quadrangle by the erosion of the San Miguel River, and extends from the Mancos (Cretaceous) shales down into the Carboniferous red beds. But in consequence of the Rico uplift and its bisection by the Dolores the lower Paleozoic formations are shown locally, and even certain quartzites of the Algonkian. The formations thus revealed in the Dolores Valley have the general character of the complete section more perfectly exposed in the Animas Valley, about 12 miles to the east. The Mesozoic formations are the same that characterize the canyons of the plateau country to the west, but it is known that most of those formations exhibit progressive changes as distance from the Colorado mountain area increases. These changes have not yet been examined in detail.

GEOGRAPHY AND TOPOGRAPHY OF THE QUADRANGLE.

The Rico quadrangle presents three especially prominent types of topographic forms, each dominating a considerable part of the area. These notable features are (1) the Dolores Plateau, (2) the Rico Mountains, and (3) the Dolores Valley, with its many lateral branches.

The Dolores Plateau.—The western half of the Rico quadrangle belongs to the Dolores Plateau. A glance at the topographic map shows that between the Dolores River and Stoner Creek there is a gently inclined mesa crossed by the western meridian of the quadrangle at an elevation of about 9400 feet. The flat crest of the narrow ridge between Stoner Creek and the West Dolores is clearly a remnant of the same plateau level and on the northern line of the quadrangle it appears again.

South of the Dolores the same notable mesa feature may be recognized. The actual extent of the mesa surface in the quadrangle may be most clearly appreciated by an examination of the geological map, where its outline is shown by means of the mapping of the distribution of the Dakota sandstone, its floor. The mesa remnants are bounded by distinct scarps formed by the sandstone.

The plateau feature gradually disappears as its sandstone floor comes under the influence of the local domal uplifts of the Rico and La Plata

the quadrangle the mes[...] cisely similar manner by [...] tains, the steeper slopes [...] two south of the quadr[...] Rico and La Plata mou[...] by the Dolores Valley a[...] the eastern side because [...] formations on this gener[...] of the broad San Juan su[...]

Almost the entire sur[...] teau remnants is cover[...] which white pine and asp[...] The mesa border southw[...] cially characterized by [...] stately aspens. At lower [...] cedar, and scrub oak [...] prominent.

The Rico Mountains.—[...] pact and rather isolated [...] area about 7 miles in di[...] and 5 miles from north [...] nearly all included withi[...] the Rico quadrangle, but [...] hundred and eighth m[...] Mountain quadrangle.

The topographic map [...] the general character of th[...] with the plateau area and [...] the Dolores Valley. Th[...] the finer details of form [...] situated east of the qua[...]

From these maps it m[...] Mountains consist of a c[...] peaks, divided into two [...] the Dolores Valley. The [...] exceeding 12,000 feet in [...] and the narrow crest con[...] below 11,500 feet on eith[...] passing through the gro[...] several important tributa[...] expose the internal structu[...] important respects. The [...] deep, with steep sides, an[...] actively engaged in the w[...]

The characteristic form[...] are illustrated in the pl[...] this folio. Fig. 1 in par[...] of form commonly presen[...] on the eastern side of the [...]

Timber line in the Rico [...] 11,500 and 12,000 feet, [...] traced in several of the ill[...]

The Dolores Valley.—[...] carved its valley through [...] Mountains, and near the [...] quadrangle it enters a ca[...] plateau level, in which it [...] the Grand River. The [...] stream within the area a[...] Creek, which heads a few [...] La Plata Mountains. Th[...] nearly as large as the ma[...] within the plateau region [...] the Dolores is at the nor[...] Mountains.

canyons have been carved by streams, one of the principal gorges being that of the Dolores River. Entering its canyon valley within the Rico quadrangle this stream flows with irregular course for about 18 miles in a southwesterly direction and then swings to a general north-northwest trend, which it maintains for over 100 miles to the Grand River.

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No surface volcanic rocks of the San Juan succession occur in the Rico quadrangle. It is probable, however, that the San Juan volcanics once extended over this area and have been removed by erosion. In support of this idea may be mentioned the fact that only a few miles north of the Rico area, on the south slopes of the San Miguel Mountains, a line of high peaks which are geologically as well as topographically western outliers of the San Juan Mountains, remnants of the horizontal surface lavas of that district, as well as great masses of intrusive rocks, are found. The base of the surface volcanics in the San Miguel peaks stands at about 12,000 feet, which is higher than any portion of the Rico quadrangle except certain points in the local area of uplift in the Rico Mountains. The Rico area is geologically related to the San Juan region chiefly in regard to pre-Tertiary formations and structure and the Quaternary erosion of streams heading on the San Juan flank.

... of the adjoining Telluride quadrangle by the erosion of the San Miguel River, and extends from the Mancos (Cretaceous) shales down into the Carboniferous red beds. But in consequence of the Rico uplift and its bisection by the Dolores the lower Paleozoic formations are shown locally, and even certain quartzites of the Algonkian. The formations thus revealed in the Dolores Valley have the general character of the complete section more perfectly exposed in the Animas Valley, about 12 miles to the east. The Mesozoic formations are the same that characterize the canyons of the plateau country to the west, but it is known that most of those formations exhibit progressive changes as distance from the Colorado mountain area increases. These changes have not yet been examined in detail.

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South of the Dolores the same notable mesa feature may be recognized. The actual extent of the mesa surface in the quadrangle may be most clearly appreciated by an examination of the geological map, where its outline is shown by means of the mapping of the distribution of the Dakota sandstone, its floor. The mesa remnants are bounded by distinct scarps formed by the sandstone.

The plateau feature gradually disappears as its sandstone floor comes under the influence of the local domal uplifts of the Rico and La Plata mountains. The contours of the map clearly express the changing dip of the Dakota sandstone, and with it the changing slope of the mesa surface itself as those mountains are approached. West of the Rico Mountains the dip slope of the mesa reaches an elevation of 11,500 feet on the ridge west of Eagle Peak. This corresponds closely to the level attained by the similar plane on the east side of Bear Creek, north of the La Plata Mountains, for across the southern part of

THE RICO QUADRANGLE.

Whitman Cross and F. L. Ransome.

ERAL GEOLOGY OF THE QUADRANGLE.

By Whitman Cross.

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the quadrangle the mesa floor is effected in precisely similar manner by the uplift of these mountains, the steeper slopes of which begin a mile or two south of the quadrangle line. Between the Rico and La Plata mountains the mesa is cut off by the Dolores Valley and does not reappear on the eastern side because of the upturning of all formations on this general line, under the influence of the broad San Juan structure.

Almost the entire surface of these mesa or plateau remnants is covered by a forest growth in which white pine and aspen are the chief elements. The mesa border southwest of Bear Creek is especially characterized by a magnificent growth of stately aspens. At lower levels piñon, white pine, cedar, and scrub oak become more and more prominent.

The Rico Mountains.—The summits of this compact and rather isolated group lie within an oval area about 7 miles in diameter from east to west and 5 miles from north to south. The peaks are nearly all included within the northeast section of the Rico quadrangle, but a few lie east of the one hundred and eighth meridian, in the Engineer Mountain quadrangle.

The topographic map of the quadrangle shows the general character of the mountains as compared with the plateau area and the long lateral ridges of the Dolores Valley. The special sheet exhibits the finer details of form and includes the peaks situated east of the quadrangle line.

From these maps it may be seen that the Rico Mountains consist of a circle of high and rugged peaks, divided into two crescent-shaped halves by

F. M. Endlich examined the district to the east, the one hundred and eighth meridian, passing through Telescope Mountain, being apparently the general western boundary of his field of work. In 1876 W. H. Holmes made a rapid reconnaissance over the plateau country to the west. The complicated geology of the Rico uplift, coming on the border zone between the fields of different men working in different seasons, did not receive adequate attention, and the Hayden map of this area is, therefore, quite unsatisfactory.

J. B. Farish and T. A. Rickard.—The only geological explorations of the quadrangle since the time of the Hayden Survey have been connected with mining developments in the Rico Mountains. In the course of descriptions of some of the mining properties near Rico there have been brief discussions of the geology of the mountain group. These discussions were for the most part founded on observations near and in the mines of Newman Hill. In 1892 John B. Farish read a paper before the Colorado Scientific Society entitled "On the Ore Deposits of Newman Hill, near Rico, Colorado" (Proc. Colorado Sci. Soc., vol. 4, pp. 151–164). The description of the ore deposits was preceded by some general remarks on the geology. The structure of the mountains was recognized by Farish as a domal uplift.

A detailed description of the Enterprise mine was published in 1896 by T. A. Rickard, then superintendent of the mine (Trans. Am. Inst. Min. Eng., vol. 26, pp. 906–980). In this paper there are but few statements concerning the general geology. The [illegible]

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Almost the entire surface of these mesa or plateau remnants is covered by a forest growth in which white pine and aspen are the chief elements. The mesa border southwest of Bear Creek is especially characterized by a magnificent growth of stately aspens. At lower levels piñon, white pine, cedar, and scrub oak become more and more prominent.

The Rico Mountains.—The summits of this compact and rather isolated group lie within an oval area about 7 miles in diameter from east to west and 5 miles from north to south. The peaks are nearly all included within the northeast section of the Rico quadrangle, but a few lie east of the one hundred and eighth meridian, in the Engineer Mountain quadrangle.

The topographic map of the quadrangle shows the general character of the mountains as compared with the plateau area and the long lateral ridges of the Dolores Valley. The special sheet exhibits the finer details of form and includes the peaks situated east of the quadrangle line.

From these maps it may be seen that the Rico Mountains consist of a circle of high and rugged peaks, divided into two crescent-shaped halves by the Dolores Valley. There are twelve peaks, each exceeding 12,000 feet in elevation above sea level, and the narrow crest connecting them rarely sinks below 11,500 feet on either side of the river. In passing through the group the Dolores receives several important tributaries on each side, which expose the internal structure of the group in many important respects. These lateral gulches are all deep, with steep sides, and their streams are still actively engaged in the work of erosion.

The characteristic forms of peaks and gulches are illustrated in the photographs reproduced in this folio. Fig. 1 in particular shows the details of form commonly present in the higher summits on the eastern side of the river.

Timber line in the Rico Mountains lies between 11,500 and 12,000 feet, and its course may be traced in several of the illustrations of the folio.

The Dolores Valley.—The Dolores River has carved its valley through the heart of the Rico Mountains, and near the western boundary of the quadrangle it enters a canyon, cut far below the plateau level, in which it flows to its junction with the Grand River. The branches of the main stream within the area are all short, except Bear Creek, which heads a few miles to the south in the La Plata Mountains. The West Dolores Valley is nearly as large as the main fork, but lies wholly within the plateau region. The extreme head of the Dolores is at the northeast base of the Rico Mountains.

The canyons of the Dolores River, Lost Canyon, Stoner Creek, and the West Dolores are characteristic of the drainage channels of the plateau country. The sides are steep and are modified by many minor scarps representing resistant sandstone strata.

GEOLOGICAL INVESTIGATION OF THE REGION.

The Hayden Survey.—The country adjacent to Rico was visited by geologists of the Hayden Survey in 1874 and 1876. In the former year F. M. Endlich examined the district to the east, the one hundred and eighth meridian, passing through Telescope Mountain, being apparently the general western boundary of his field of work. In 1876 W. H. Holmes made a rapid reconnaissance over the plateau country to the west. The complicated geology of the Rico uplift, coming on the border zone between the fields of different men working in different seasons, did not receive adequate attention, and the Hayden map of this area is, therefore, quite unsatisfactory.

J. B. Farish and T. A. Rickard.—The only geological explorations of the quadrangle since the time of the Hayden Survey have been connected with mining developments in the Rico Mountains. In the course of descriptions of some of the mining properties near Rico there have been brief discussions of the geology of the mountain group. These discussions were for the most part founded on observations near and in the mines of Newman Hill. In 1892 John B. Farish read a paper before the Colorado Scientific Society entitled "On the Ore Deposits of Newman Hill, near Rico, Colorado" (Proc. Colorado Sci. Soc., vol. 4, pp. 151–164). The description of the ore deposits was preceded by some general remarks on the geology. The structure of the mountains was recognized by Farish as a domal uplift.

A detailed description of the Enterprise mine was published in 1896 by T. A. Rickard, then superintendent of the mine (Trans. Am. Inst. Min. Eng., vol. 26, pp. 906–980). In this paper there are but few statements concerning the general geology. The strata about Rico are said to be fossiliferous and to belong to the lower Carboniferous, and the common igneous rock is called porphyrite, and is concisely described by R. C. Hills. Rickard refers to "a large dike of porphyrite" crossing the valley north of Rico, "making a fault which breaks the continuity of the country on either side." It would appear that this reference must be to the mass of schists with small dikes of hornblendic porphyry; but the position and importance of the fault are not further indicated.

U. S. Geological Survey.—In the course of the present resurvey of the Rico quadrangle the geologic complications in the Rico Mountains were found to be so great that a detailed topographic map and a special report on its geology and mineral resources were found necessary. This report appeared in the Twenty-first Annual Report of the Geological Survey under the title, "Geology of the Rico Mountains, Colorado," by Whitman Cross and Arthur Coe Spencer. As the Rico Mountains are the most important and most complex part of the quadrangle the text of this folio is in large degree descriptive of the phenomena exhibited in the mountains. But as only the broader features of the geology can be treated in this place the reader will often be referred for details to the publication just cited, which will be called in general terms "the Rico report." The special map of that report is republished in this folio as the economic sheet.

A report on the ore deposits of the Rico Mountains, by Frederick Leslie Ransome, appeared in the Twenty-second Annual Report of the Geological Survey, Part II, pp. 229–397. A summary of that report constitutes the section of this folio on "Economic geology."

Folios presenting the geology of the Telluride quadrangle on the northeast and of the La Plata quadrangle on the south have been issued. Those of the Engineer Mountain and Durango quadrangles, respectively east and southeast of Rico, are in preparation.

CULTURE.

The agricultural development within the Rico quadrangle is limited to small areas of bottom land, principally in the valley of the West Dolores and to a less extent in that of the main river. The level expanses of the plateau are not available for cultivation, because of the lack of water. They afford excellent grazing land in many places.

Metalliferous deposits in the Rico Mountains have led to extensive mining operations and the foundation of the town of Rico, situated on the river in the heart of the mountain group. The Rio Grande Southern Railroad crosses the quadrangle, following the valley of the Dolores River.

DESCRIPTIVE GEOLOGY.

THE ROCK FORMATIONS.

SEDIMENTARY AND METAMORPHIC ROCKS.

ALGONKIAN SYSTEM.

Algonkian =
Late Precambrian

Introductory statement.—The rocks which are described as Algonkian occupy a small area in the center of the Rico Mountains, where they have been exposed by the carving of the Dolores Valley through the heart of the uplift. They comprise quartzites and quartzitic schists and are similar to the series of rocks exposed in the Uncompahgre Canyon on the north side of the San Juan Mountains and in the Needle Mountains on the south side of the San Juan. In the latter region they were represented on the Hayden map as "metamorphic Paleozoic."

The quartzites of the Animas Canyon section through the Needle Mountains have been examined by Emmons and Van Hise, who have assigned them to the Algonkian system. The correctness of this assignment is confirmed by recent work of the Geological Survey in the Needle Mountains and the discovery of Cambrian fossils in the lowest Paleozoic formation of that area, which rests unconformably on the quartzites and other pre-Cambrian rocks. In the Silverton folio the quartzites, slates, and conglomerates of this ancient complex were called the Uncompahgre formation. The Uncompahgre quartzites and slates are underlain in the Needle Mountains by a thick conglomerate called the Vallecito formation. The Vallecito and the Uncompahgre together constitute the Needle Mountains group, according to the nomenclature proposed in the Needle Mountains folio.

UNCOMPAHGRE FORMATION.

Character.—The Algonkian rocks, very imperfectly exposed at Rico, consist of quartzites and quartzitic schists bearing small amounts of mica. The quartzites are found only in the valley of Silver Creek, in small upthrust fault blocks, and are not distinguishable in character from other massive quartzites, to be described later, which are supposed to be of Cambrian age; but the visible thickness and the structural attitude of the Algonkian rocks make it impossible to refer them to the thin Cambrian formation of this region. They are white or tinged with brown, with occasional red or rusty bands. They are composed almost entirely of quartz, occurring usually in small, even-grained particles, but sometimes in the form of pebbles less than an inch in diameter. The rock is completely indurated by the interstitial deposition of quartz, so that it is now glassy quartzite, very resistant to erosion. Distinct partings between the beds of quartzite are nowhere observable in present exposures. However, the bedding or stratification planes may frequently be made out from a study of the massive quartzites, where differences of grain are found or where cross-bedding is observable. Ripple-marked surfaces are also occasionally seen.

Occurrence.—There are six separate areas of quartzite in the valley of Silver Creek, and of these one, that below Allyn Gulch, is certainly Algonkian, as must be inferred from its great mass; another, on the opposite side of Silver Creek, is probably of that age; while the others have been assigned to the Paleozoic. In the place first mentioned the ... elevations of 9200 and 9500 feet, showing a continuous exposure at one place to a thickness of 350 feet, though from the structure it is probable that a greater thickness is present. The strike and dip may be determined in this region and, while both are variable, the former is generally about N. 10°-30° E. and the latter is steeply toward the south of east. On the north, south, and west the boundaries of this mass of quartzite are not known, since they are covered by surface débris; but from the adjacent occurrences of porphyry belonging to the thick sill of Newman Hill it is almost certain that the quartzite is limited on the south and west by faults, in the manner indicated on the map, while on the north it may connect underneath the valley wash with the quartzite on the north side of Silver Creek.

Within the area just mentioned the rocks are very imperfectly exposed, except in local patches, but from these and from the data derived from tunnels and prospects it is definitely known that the northern limit is along the Last Chance fault, which has a nearly east-west course. The highest exposures are near this fault, at about 9400 feet, and the quartzite can not extend much beyond this point, since green shales and sandstones are exposed at about the same elevation in the draw below the Alma Mater mine.

SCHIST.

Character.—The remaining rocks of probable Algonkian age may be termed schists, since they have a more or less distinct foliated structure, not due to original bedding, but superinduced by metamorphism under stress. In these schists the stratification may be made out in some cases by differences in the character of adjacent bands, and to this structure the foliation is generally, though not always, parallel. The direction of foliation does not vary greatly from east and west, and its position is nearly vertical wherever observed.

The schists are dense bluish-gray rocks, the foliation being caused by the arrangement of very minute particles of biotite and actinolite, not recognizable to the unaided eye. A delicate luster is visible on the planes of easier fracture, but the schistosity is never very highly developed and the rocks often break readily across the structure with almost conchoidal fracture.

In a few places the rock has quite clearly the character of a mashed product, apparently derived from a porphyry in which there were phenocrysts of quartz and feldspar. There is a slight development of tourmaline in such rocks.

Intruded into these schists, in general parallel to the structure, but sometimes crosscutting, are many thin dikes of a dark porphyritic rock. These are prominent on both sides of the river, but have not been found in the Algonkian quartzites nor in any other rock than the schists; hence they are supposed to be very old intrusions, independent of the other eruptions of the region. This idea is substantiated by the mashing of some of the dikes. Stout prisms of hornblende are the only prominent crystals of the rock. There is also much secondary hornblende and epidote revealed by the microscope. The former, subordinate feldspathic constituent is so much crushed and altered that the original character can not be determined. Plagioclase was probably predominant over orthoclase.

Occurrence.—The Algonkian schists occur only in the Dolores Valley just above Rico in small upthrust fault blocks, and the structure about them is so complicated, as shown by the special sheet, that the relations of the schists to the Algonkian quartzites and of the latter to small areas of Paleozoic quartzites have not been satisfactorily demonstrated in all cases.

CAMBRIAN (?) SYSTEM.

IGNACIO QUARTZITE.

Introductory statement.—The lowest member of the Paleozoic section displayed in the Rico Mountains is a quartzite which was grouped with the overlying limestone in the Rico report, both being referred to the Devonian, though with a re-eva- ...

mation deserving recognition ... quartzites and the Devonian ... intermediate formation consist- ... Animas Valley, of thin-bedd ... calcareous shales with varying ... quartzites, the whole less than ... ness. Fragments of fish scales ... found in these beds and althoug ... cally determinable forms have ... is considered probable by Dr. (... has studied them, that these fo... closely related to fish remains ... kill formation of the upper D... sylvania. In the Silverton fol... series of beds was named the ... The observations made at Rico ... presence of the Elbert beds at ... is possible that the limited expo... or less metamorphosed condition ... have hindered recognition of ... features of this formation.

The lowest lithologic division ... section in the Animas Valley is ... ites, and varies in thickness fr... to 200 feet. A single fossil sh... Charles D. Walcott as *Obolus* sp... certain Upper Cambrian species, ... these quartzites, and therefore it ... best to refer the formation to th... togan series of the Cambrian. ... folio this was named the Ignaci... its occurrence near the Ignacio L... neer Mountain quadrangle.

The Ignacio beds at Rico.—Th... provisionally referred to the I... may be seen in the bed of the D... above Rico and along the west ba... These strata dip at an angle of a... ward, passing under the minerali... the Atlantic Cable claim. They ... beneath that limestone in the bo... the claim mentioned. It is pr... quartzites reach a thickness of at ...

This basal quartzite is a ma... dense and highly indurated. It... yellow-white with red and brown ... a slight variation in grain, the mas... being fairly homogeneous. The ... sometimes discernible, though ... by jointing and rifting. The ... clearly distinguishable from the A... ite except by its more regular bed... conformable attitude which it be... lying Paleozoic rocks.

Occurrence.—The most clearly ... ites of the Ignacio formation occur ... the Dolores River, just north of R... The Smelter fault. Certain other ... are associated with Algonkian schi... of the river near the Last Chance ... been referred to this formation. St... ites, mapped as Devonian on the sp... panying the Rico report, occur i... Silver Creek. These quartzites se... conformity with the Carbonifero... man Hill. If they are Cambrian ... absence of the Devonian limeston... must be explained. In the Rico r... the reader must be referred for fu... of this question, it was assumed tha... limestone had been removed by ... point before the deposition of the ... boniferous).

DEVONO-CARBONIFEROUS S...

OURAY LIMESTONE.

Name and definition.—The pre... nian strata in southwestern Colo... recognized in 1874, through colle... made by F. M. Endlich, of the Hayd... the southern slopes of the Needl... The name Ouray limestone was prop... Spencer, in 1900, after the strata h... amined in connection with the U. ... Survey work, from the town of O... southern border of which is a ...

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mation deserving recognition occurs between the quartzites and the Devonian limestone. This intermediate formation consists, as known in the Animas Valley, of thin-bedded limestones and calcareous shales with varying amounts of thin quartzites, the whole less than 100 feet in thickness. Fragments of fish scales and bones have been found in these beds and although but a few specifically determinable forms have yet been obtained, it is considered probable by Dr. C. R. Eastman, who has studied them, that these fossils are identical or closely related to fish remains occurring in the Catskill formation of the upper Devonian, in Pennsylvania. In the Silverton folio the fish-bearing series of beds was named the Elbert formation. The observations made at Rico do not indicate the presence of the Elbert beds at that locality, but it is possible that the limited exposures and the more or less metamorphosed condition of the rocks may have hindered recognition of the characteristic features of this formation.

The lowest lithologic division of the Paleozoic section in the Animas Valley is made up of quartzites, and varies in thickness from a few feet up to 200 feet. A single fossil shell, determined by Charles D. Walcott as *Obolus* sp.? and resembling certain Upper Cambrian species, has been found in these quartzites, and therefore it seems at present best to refer the formation to the upper or Saratogan series of the Cambrian. In the Silverton folio this was named the Ignacio formation, from its occurrence near the Ignacio Lakes in the Engineer Mountain quadrangle.

The Ignacio beds at Rico.—The quartzites here provisionally referred to the Ignacio formation may be seen in the bed of the Dolores River just above Rico and along the west bank of the stream. These strata dip at an angle of a few degrees southward, passing under the mineralized limestone of the Atlantic Cable claim. They were encountered beneath that limestone in the bore hole sunk on the claim mentioned. It is probable that the quartzites reach a thickness of at least 200 feet.

This basal quartzite is a massive rock, very dense and highly indurated. Its colors are dull yellow-white with red and brown stains. There is a slight variation in grain, the mass of the formation being fairly homogeneous. The stratification is sometimes discernible, though usually obscured by jointing and rifting. The formation is not clearly distinguishable from the Algonkian quartzite except by its more regular bedding and by the conformable attitude which it bears to the overlying Paleozoic rocks.

Occurrence.—The most clearly defined quartz-
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of Devonian age. It was supposed by Spencer that the whole limestone complex in question must be of Devonian age, but as will be shown, it has been proved that an indefinite but subordinate part of the most prominent limestone ledge of the Ouray is Mississippian. Since it is impossible to draw a line between the two portions, the Ouray becomes a lithologic unit transgressing the faunal boundary between the Devonian and Carboniferous systems.

General lithologic character.—The Ouray formation as at present known has a thickness varying from 100 to 300 feet. The upper and major part of the formation is massive limestone, either in one bed or with such thin intercalated shale that the ability of the limestone to resist erosion and thus to cause mesas, benches, and prominent cliffs as characteristic topographic forms, is always notable. Below the more massive portion a third or less of the section is made of well-bedded limestone with distinct shaly layers and, rarely, thin quartzites, between them. Some of the lower layers have a wavy bedding, some are arenaceous or earthy, and large chert concretions, free from fossils, are common at a horizon near the base. The lowest stratum is characterized usually by crinoid stems and rarely a cup coral.

The greater part of the formation is dense, compact limestone, but portions of the upper ledge are coarsely crystalline. In general, the rock is nearly white, straw yellow, or buff, with local pinkish tones. Some of the lower beds are strongly yellow and these are commonly more or less sandy. The contrast with the dark-gray, dense limestone of the Hermosa is marked, layers of such character occurring only near the base of the Ouray.

The Carboniferous portion of the Ouray is lithologically indistinguishable from the Devonian.

Faunas and correlation.—The Devonian invertebrate fauna of the Ouray occurs from near the base to a horizon which in many places is not far below the top of the upper, massive ledge. The greater number of species occur in this upper horizon, but many of them range to within a few feet of the base.

The Mississippian fauna has been found at several localities in the Animas Valley in coarsely crystalline beds near the top of the formation.

Fossils have not been found at Rico, but have been obtained at Ouray and at several localities on the southern slope of the San Juan, including that where Endlich first found a few characteristic Devonian species.

The invertebrate fauna of the Devonian portion of the Ouray has been fully described by G. H.
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UNCOMPAHGRE FORMATION.

Character.—The Algonkian rocks, very imperfectly exposed at Rico, consist of quartzites and quartzitic schists bearing small amounts of mica. The quartzites are found only in the valley of Silver Creek, in small upthrust fault blocks, and are not distinguishable in character from other massive quartzites, to be described later, which are supposed to be of Cambrian age; but the visible thickness and the structural attitude of the Algonkian rocks make it impossible to refer them to the thin Cambrian formation of this region. They are white or tinged with brown, with occasional red or rusty bands. They are composed almost entirely of quartz, occurring usually in small, even-grained particles, but sometimes in the form of pebbles less than an inch in diameter. The rock is completely indurated by the interstitial deposition of quartz, so that it is now glassy quartzite, very resistant to erosion. Distinct partings between the beds of quartzite are nowhere observable in present exposures. However, the bedding or stratification planes may frequently be made out from a study of the massive quartzites, where differences of grain are found or where cross-bedding is observable. Ripple-marked surfaces are also occasionally seen.

Occurrence.—There are six separate areas of quartzite in the valley of Silver Creek, and of these one, that below Allyn Gulch, is certainly Algonkian, as must be inferred from its great mass; another, on the opposite side of Silver Creek, is probably of that age; while the others have been assigned to the Paleozoic. In the place first mentioned the quartzites have their greatest development. They are bounded on the east by a well-marked fault, shown in the Laxy mine; thence toward the southwest they may be traced for a quarter of a mile along the hillside, on the slope of which their outcrops are to be seen between the ation being caused by the arrangement of very minute particles of biotite and actinolite, not recognizable to the unaided eye. A delicate luster is visible on the planes of easier fracture, but the schistosity is never very highly developed and the rocks often break readily across the structure with almost conchoidal fracture.

In a few places the rock has quite clearly the character of a mashed product, apparently derived from a porphyry in which there were phenocrysts of quartz and feldspar. There is a slight development of tourmaline in such rocks.

Intruded into these schists, in general parallel to the structure, but sometimes crosscutting, are many thin dikes of a dark porphyritic rock. These are prominent on both sides of the river, but have not been found in the Algonkian quartzites nor in any other rock than the schists; hence they are supposed to be very old intrusions, independent of the other eruptions of the region. This idea is substantiated by the mashing of some of the dikes. Stout prisms of hornblende are the only prominent crystals of the rock. There is also much secondary hornblende and epidote revealed by the microscope. The former subordinate feldspathic constituent is so much crushed and altered that the original character can not be determined. Plagioclase was probably predominant over orthoclase.

Occurrence.—The Algonkian schists occur only in the Dolores Valley just above Rico in small upthrust fault blocks, and the structure about them is so complicated, as shown by the special sheet, that the relations of the schists to the Algonkian quartzites and of the latter to small areas of Paleozoic quartzites have not been satisfactorily demonstrated in all cases.

CAMBRIAN (?) SYSTEM.

IGNACIO QUARTZITE.

Introductory statement.—The lowest member of the Paleozoic section displayed in the Rico Mountains is a quartzite which was grouped with the overlying limestone in the Rico report, both being referred to the Devonian, though with a reservation as to the quartzite, since it was recognized that that formation might be much older than the limestone. Recent investigations in the quadrangles lying east of the Rico have shown not only that the quartzites are probably of Saratogan (Upper Cambrian) age, but that another thin for- quartzites reach a thickness of at least 200 feet.

This basal quartzite is a massive rock, very dense and highly indurated. Its colors are dull yellow-white with red and brown stains. There is a slight variation in grain, the mass of the formation being fairly homogeneous. The stratification is sometimes discernible, though usually obscured by jointing and rifting. The formation is not clearly distinguishable from the Algonkian quartzite except by its more regular bedding and by the conformable attitude which it bears to the overlying Paleozoic rocks.

Occurrence.—The most clearly defined quartzites of the Ignacio formation occur in the valley of the Dolores River, just north of Rico and south of the Smelter fault. Certain other quartzites, which are associated with Algonkian schists on both sides of the river near the Last Chance fault, have also been referred to this formation. Still other quartzites, mapped as Devonian on the special map accompanying the Rico report, occur in the valley of Silver Creek. These quartzites seem to occur in conformity with the Carboniferous rocks of Newman Hill. If they are Cambrian, however, the absence of the Devonian limestone above them must be explained. In the Rico report, to which the reader must be referred for further discussion of this question, it was assumed that the Devonian limestone had been removed by erosion at this point before the deposition of the Hermosa (Carboniferous).

DEVONO-CARBONIFEROUS ROCKS.

OURAY LIMESTONE.

Name and definition.—The presence of Devonian strata in southwestern Colorado was first recognized in 1874, through collections of fossils made by F. M. Endlich, of the Hayden Survey, on the southern slopes of the Needle Mountains. The name Ouray limestone was proposed by A. C. Spencer, in 1900, after the strata had been reexamined in connection with the U. S. Geological Survey work, from the town of Ouray, on the southern border of which is a prominent outcrop of the limestone.

The name was proposed by Spencer for the Devonian limestone member of the pre-Carboniferous Paleozoic, excluding the quartzites and shales here called the Ignacio and Elbert formations, although they were thought to be possibly greater number of species occur in the upper horizon, but many of them range to within a few feet of the base.

The Mississippian fauna has been found at several localities in the Animas Valley in coarsely crystalline beds near the top of the formation.

Fossils have not been found at Rico, but have been obtained at Ouray and at several localities on the southern slope of the San Juan, including that where Endlich first found a few characteristic Devonian species.

The invertebrate fauna of the Devonian portion of the Ouray has been fully described by G. H. Girty, and compared with similar faunas hitherto collected in Colorado, but not recognized as distinct from the forms of the Mississippian. It is represented more or less fully in older collections from the Elk Mountains, at Glenwood Springs on Grand River, near the head of White River, and on East Monarch Mountain, Chaffee County. Full correlations of the sections in these localities with that of the San Juan region can not be made, however, until further examinations have been carried out. Concerning the fauna Mr. Girty writes:

> In general the Devonian fauna of the Ouray belongs to late middle or, more probably, to upper Devonian time. It is but distantly related to the Devonian faunas of New York, and its relation with those of the Mississippi Valley, or even with other known western Devonian faunas, is not close. It shows many points of approximation to the Athabascan fauna described by Whiteaves, and is somewhat strikingly similar to the Devonian of Russia.

The following named species are particularly characteristic of the Devonian portion of the Ouray fauna:

Schuchertella Chemungensis	*Camarotœchia Endlichi.*
Productella semiglobosa.	*Camarotœchia contracta?*
Athyris Coloradoensis.	*Natleopsis? humilis.*
Spirifer conicultus.	*Orthoceras sp.*
Spirifer disjunctus var. Animasensis.	

As to the Mississippian fauna of the Ouray limestone Mr. Girty makes the following statement:

> The fauna which at one time occupied the higher beds of the Ouray limestone is very different from the assemblage of Devonian types which occurs below, and belongs to a phase of Carboniferous life which was widely distributed over the continental sea. It is found in the

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cases the preservation of the mountains as regions of high topographic relief is due to the presence of igneous rocks which have been more resistant to erosion than the sediments would have been alone. The intrusions are in the form of stocks, dikes, and sheets. To the latter, which may in some cases have sufficient thickness to be of the type known as laccoliths, a certain amount of the observed deformation of the stratified rocks is certainly due. In the La Plata Mountains the mass of intruded matter of this nature shown in the horizons exposed is comparable to the deformation which they have suffered over and above that affecting the lower formations, which are covered and therefore beyond observation; so that if the porphyry included in the hidden strata should bear the same proportion to the sedimentary rocks as in the observed section, the doming should be accounted for without additional uplift. At Rico the structure and make-up of the dome is much better exhibited, and though the theory that the observed structure might be due to a huge laccolith lying between the Algonkian and Paleozoic rocks was at one time entertained as a working hypothesis, it is now known that such a mass of igneous rock does not exist, and that the amount of deformation which the uppermost strata of the region underwent was several times in excess of the amount of igneous material which was intruded into the strata below them; that is, the formation of the Rico dome is mainly due to a central uplifting force, apart from any actual intrusions of liquid rock material. That such a force was also active in the La Plata uplift may well be believed, for there, as at Rico, the thickest laccoliths or sills occupy a zone, so far as the rocks now remaining are able to show, at a distance from the center of the dome, and it is on these peripheral intrusions that the estimate of the sufficiency of the porphyries to produce the observed structure was based.

THE RICO MOUNTAINS.

It has already been pointed out that there are three natural topographical and geological divisions of the Rico quadrangle, viz, the Rico Mountains, the Dolores Plateau, and the main Dolores Valley. The formations of the quadrangle and the general geologic structure determining their attitude and distribution having been discussed, it does not seem necessary to give further descriptive details concerning the plateau and valley areas, the geology of which is very simple. But the Rico Mountains are so complex in structure, igneous phenomena, and other respects that a résumé of their prominent features is desirable.

The Rico Mountains have been carved out of the domal uplift of several elements, already described. Naturally the peaks exhibit most clearly the formations taking part in the dome and their structure, while the deep dissection by the Dolores and its branches displays the features of the core of the uplift. The exhibition of the latter geologic detail is, however, greatly obscured by the superficial landslide materials, which assume a position of much local importance.

THE CIRCLE OF PEAKS.

The main summits of the Rico group arrange themselves in harmony with the domal structure in a circular zone. They are remarkably uniform in height, a dozen peaks exceeding 12,000 feet in elevation, while the highest, Blackhawk, is but 12,677 feet, or 4000 feet above the river at Rico. The Dolores River divides the group into two nearly equal crescents.

EASTERN SUMMITS.

Mountains south of Silver Creek.—While nearly all the peaks of the Rico group exhibit many characteristic features of the local geology, those lying to the south of Silver Creek are most note-

slopes of Dolores Mountain seen in the central part of the view, and by many lines in the higher summits, due to stratification or to intercalated sheets of porphyry.

The higher portions of all these peaks consist of the red Cutler or Dolores strata with sharply contrasting grayish porphyries. Excellent sections of parts of the Cutler are to be found in several places, one on the slope of Whitecap Mountain being shown in the figure. The presence of a thin limestone conglomerate of the fossiliferous section of the Dolores very near the summit of Blackhawk Peak shows the projected horizon of the La Plata sandstone to be but a few hundred feet above that mountain.

The influence of faulting is not self-evident in this illustration, yet the magnitude of the displacement on the Blackhawk fault is really shown, for the prominent limestone band of the Dolores Mountain slope is dropped on that fault to a level too low to permit its appearing within the field of this view on the farther side of Allyn Gulch.

The faults of this area are clearly shown in many places by their dislocation of porphyry sheets, but the grassy or timbered slopes seen in fig. 1 often hinder a connected tracing out of some of them. The splitting of the Blackhawk fault and the gradual decrease of dislocation are plainly visible on the slopes of Blackhawk Peak.

It may be seen from fig. 1 how well the occurrence of intrusive porphyry masses is exhibited on Whitecap Mountain and the narrow divide at the head of Deadwood Gulch. There are numerous other points at which these relations can be seen to advantage. One of these is on the high northern spur of Blackhawk Peak, where a large sheet makes cliffs several hundred feet high, shown in fig. 1. This mass extends around the head of Silver Creek, covering a large surface, as shown in part by the special map. The crosscutting relations of these porphyries, as they pass more or less obliquely from one horizon to another, are very plainly indicated.

In the Rico report may be found several views which will assist the reader in comprehending the character of this portion of the mountains. One of these views presents the country lying east of Blackhawk Peak.

Telescope Mountain and vicinity.—The northeastern quadrant of the Rico Mountains is comparatively simple in its geologic structure and possesses but one mountain summit of prominence—Telescope Mountain. The Cutler red beds here assume almost exclusive surface importance, through their duplication by the Telescope Mountain fault. They are overlain by the Dolores formation at a short distance east of the area covered by the special map. The high divide running irregularly east from Telescope Mountain, which forms the watershed between the head of the Dolores River and Hermosa Creek, a branch of the Animas River, has many high points above timber line in which the several formations may be studied.

The Rico and upper Hermosa beds form a scarp facing the landslide area of C. H. C. Hill on the northwest ridge from Telescope Mountain as shown in fig. 5. The general structure of the mountain may also be seen in this view from exposures near the summit.

The minor faults of this region are conspicuous through dislocation of porphyry sheets, while the largest fault of the mountains is scarcely identifiable on the ground.

The porphyry intrusions of this section of the Rico Mountains are less in number and magnitude than in any other part, being limited to a few thin sheets and dikes in the upper half of the Dolores formation. It is worthy of note, however, that a large laccolith occurs just above the Dakota sandstone about one-half mile beyond the northeast corner of the area covered by the special map, on the

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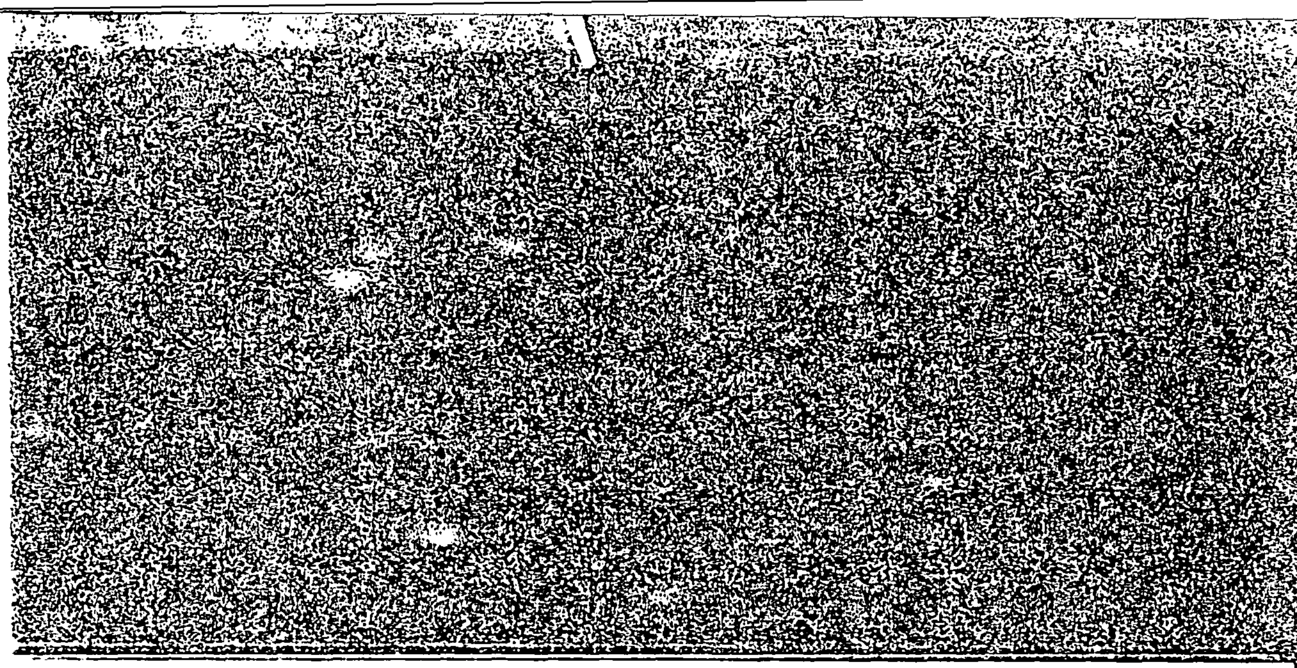

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the summit of Telescope Mountain. The entire area represented on the map as landslide territory exhibits the characteristic topographic detail. At the upper limit and on the southern border of the landslide tract seen in the view there is evidence of recent movement. In the Rico report may be found a picture of a tree split in two by movement now in progress, and even more convincing evidence is exhibited in the crushed or twisted timbers of mine workings throughout the tract.

Many small landslides have occurred on the northern slope of Telescope Mountain, but the blocks have broken up thoroughly in their fall and can scarcely be distinguished from ordinary avalanche débris.

WESTERN SUMMITS.

Mountains north of Horse Gulch.—The domal structure of the Rico Mountains, causing sedimentary beds to dip away from the center, is well shown in the high ridge leading from Sandstone Mountain through Elliott Mountain and northward across the quadrangle line. The general attitude of the strata on this line is represented in the view of Sandstone Mountain and the next higher point on this ridge, forming fig. 2 of the illustration sheet. The Jurassic and Dakota (Cretaceous) formations on the divides leading outward from Elliott, Sockrider, and Johnny Bull mountains exhibit the same structure.

Elliott Mountain is conspicuous in contrast to other peaks of the group by reason of the light-colored La Plata sandstone, which forms cliffs below the capping mass of porphyry.

The few faults of this area illustrate the lack of system in these fractures, and none of them produces results very marked in the present topography.

The porphyries of this district illustrate several intrusive relations of interest. The laccolithic form is fairly well shown in the mass of Elliott Mountain, the remnant of which is over 600 feet thick beneath the summit, while the porphyry is not present across the saddle north of the mountain. There are many sheets and small dikes and the forking or crosscutting of some of these bodies is clearly exhibited.

In one of the branches of Horse Gulch is very imperfectly exposed the rock of what may be one springs which give off strong odors of sulphureted hydrogen, near the head of Stoner Creek and on Johnny Bull Creek not far from Calico Peak.

The appearance of Calico Peak, with its talus heaps, less the vivid colors, is shown in Pl. VII of the Rico report.

Anchor and Expectation mountains.—Between the heads of Horse and Burnett gulches are two high peaks, Anchor and Expectation mountains, in which the crosscutting and branching of intrusive porphyry sheets is exemplified in many places. Indeed, so numerous are the visible forkings of the porphyry masses here that the conclusion seems by no means far fetched that all the more or less irregular masses shown by the map in the northwest-southeast zone from Johnny Bull Creek to beyond Landslip Mountain belong to one intrusion. The rocks are visibly different only in minor details of texture.

Peaks southwest of Burnett Gulch.—The southwestern summits of the Rico group exhibit the Cutler and Dolores red beds in their normal position dipping away from the center of the dome. On the ridge leading south from Storm Peak the La Plata and McElmo formations are seen in typical development. The porphyry bodies in the red beds have been referred to as probably connected with those of Anchor Mountain.

The most interesting local feature of this section is the landslide mass on the south slope of Landslip Mountain. This occurrence illustrates very well the various phases in the history of a landslide area, from the newly fallen blocks seen here adjacent to the summit of the mountain, through the older, partially disintegrated masses of the middle slopes, to the forest-covered débris near the stream below, where sinks and trenches still demonstrate the existence of slide masses.

Darling Ridge.—Between Horse and Sulphur gulches is a high tract cut almost in two by the head of Iron Draw. Here occurs the large stock of granular rock, quartz-monzonite, which appears to have been one of the later intrusions, if not the last, of the Rico center. The contacts of this stock are not well shown at any point, mainly on account of the shattered condition of the monzonite mass, which has resulted in talus or loose broken-rock piles, where larger landslides have not taken place. The metamorphosed condition of the sedimentary rocks on either side of the monzonite on Darling does not seem necessary to give further descriptive details concerning the plateau and valley reas, the geology of which is very simple. But he Rico Mountains are so complex in structure, gneous phenomena, and other respects that a ésumé of their prominent features is desirable.

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EASTERN SUMMITS.

Mountains south of Silver Creek.—While nearly all the peaks of the Rico group exhibit many characteristic features of the local geology, those lying to the south of Silver Creek are most noteworthy, because they show not only the domal structure, but the effects of faulting and igneous intrusion, and the sedimentary section is more completely displayed than elsewhere, on account of the comparatively insignificant development of landslide masses.

Fig. 1 illustrates many features of these peaks as seen from the west side of the Dolores, looking nearly due east. The prevalent dip to the southeast is particularly brought out by certain massive limestones of the upper Hermosa, which cross the paratively simple in its geologic structure and possesses but one mountain summit of prominence—Telescope Mountain. The Cutler red beds here assume almost exclusive surface importance, through their duplication by the Telescope Mountain fault. They are overlain by the Dolores formation at a short distance east of the area covered by the special map. The high divide running irregularly east from Telescope Mountain, which forms the watershed between the head of the Dolores River and Hermosa Creek, a branch of the Animas River, has many high points above timber line in which the several formations may be studied.

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The porphyry intrusions of this section of the Rico Mountains are less in number and magnitude than in any other part, being limited to a few thin sheets and dikes in the upper half of the Dolores formation. It is worthy of note, however, that a large laccolith occurs just above the Dakota sandstone about one-half mile beyond the northeast corner of the area covered by the special map, on the farther side of Barlow Creek. This mass is the Flattop laccolith, a portion of which is situated in the Telluride quadrangle. It is not clear that this large intrusion has actual genetic connection with the Rico center, as will be explained in the discussion of the intrusions under "Geological history."

The landslide phenomena of Telescope Mountain proper are so clearly exhibited in fig. 5 as to require little further comment. The actual head of the slide area is on the ridge leading southwest to Nigger Baby Hill and less than 500 feet below of the principal centers of eruption. The porphyry is here seen to cut across the sediments, sending off numerous dikes and thin sheets. It is full of apparent inclusions and is penetrated by many angular arms of the wall rock. Unfortunately there has been great decomposition here and in addition the extremely complex relations are obscured to a large extent by soil, forest growth, and wash, so that the representation of the map is in some degree diagrammatic. In spite of these conditions, this locality is an excellent one in which to study complex intrusive relations.

Eagle Peak.—The westernmost of the Rico Mountains exceeding 12,000 feet in elevation is Eagle Peak. It lies beyond the line limiting the distribution of visible porphyry masses and therefore presents in least distorted form the simple structural relations of the sedimentary rocks taking part in the domal structure. Passing from the peak along the ridge to the west one has excellent opportunity to examine sections of the La Plata, McElmo, and Dakota formations and to observe the change from the domal structure to that of the Dolores Plateau.

Calico Peak.—The variegated coloring exhibited by the decomposed rock of this summit at the head of Horse Gulch has led to the current name Calico Peak. The original porphyry of this peak has been almost completely altered to a mass of alunite, kaolin, and quartz, impregnated with pyrite, the oxidation of which has produced the vivid red and yellow colors now so striking. Apparently the rock occurs as a small stock, although its contacts are concealed by talus or slide. It is supposed that the rock was similar to the porphyry of large orthoclase phenocrysts, of which a long dike crosses the slope of Johnny Bull Mountain, and which occurs only in this vicinity.

The formation of alunite is referable to sulphurous emanations, either directly by gases or indirectly through waters which have absorbed gases. That such activity has been specially marked in this vicinity is shown by existing Ridge is everywhere evidence of the proximity of the contact.

Although the monzonite body is large and such massive rocks usually cause rugged topography, such is not here the case. This fact is probably due to the thoroughly shattered condition of the stock, leading to rapid destruction of prominences by frost. The large number of small knobs and knolls, often with pinnacled spurs or summits, situated on the north side of Darling Ridge, are plainly separated by zones of fracture and brecciation and are themselves crumbling to pieces under frost action. The assignment of these knolls to the landslide area will be discussed in the next section of the text.

THE INNER SLOPES OF THE MOUNTAINS.

From the preceding description of the domal structure of the Rico Mountains and of the circle of prominent peaks it will be plain to the reader that the outer slopes of the mountain group exhibit simple structural relations of sedimentary formations and that igneous masses are few. It does not seem necessary, therefore, to give further descriptions of the peripheral portion of the Rico dome. In the heart of the mountains, where the structural complexities are great, where several formations not occurring elsewhere in the quadrangle have been revealed by the deep erosion of the Dolores and its tributaries, and where many intrusive bodies appear, the case is quite different. Here, however, the phenomena of local interest are so numerous that the reader must be referred to the Rico report for the greater part of the detail; the present descriptions will be confined to certain of the larger features of importance. In fact, it is not the fundamental relations of the formations, but rather the way in which these relations have been obscured, which will receive most attention.

LANDSLIDE AREAS OF HORSE GULCH.

The map and figs. 3, 5, and 6 of the illustration sheet show how completely the normal structure apparently splits into two or more small sheets before crossing the river, and many other irregularities may well be assumed to exist.

That this large porphyry body is in the main of laccolithic character is further indicated by the limited exposure of its base in the workings of the South Park mine in Silver Gulch. Several very small dikes or sheets of porphyry have been encountered in the mines of Newman Hill.

GEOLOGICAL HISTORY.

PRE-TERTIARY EVENTS.

Introductory.—The visible record of pre-Tertiary events in the geologic development of this area lies wholly in the sedimentary formations and their stratigraphic relations. From the discussion of the formations already given it appears that the section is nearly like that much better exposed, in its lower portions at least, in the Animas Valley. No marked local characteristic has been observed in the Rico formations of pre-Tertiary age, so that the course of events here can only be assumed to have been that of the surrounding province, an outline of which has been presented in the Telluride and Silverton folios. For the present folio it is considered sufficient to refer very briefly to the history preceding the continental uplift of the whole sedimentary section, in post-Laramie time.

Pre-Paleozoic era.—From the study of the Needle Mountains and the Animas Canyon sections it appears that the oldest rocks of this region are certain gneisses and schists, supposed to be of Archean age. The next younger series of rocks consists largely of igneous material, greatly metamorphosed and associated with some distinct sediments. Following the accumulation of this complex came a long period of sedimentation during which the Uncompahgre group of conglomerates, sandstones, and shales was deposited, in marked unconformity with the structures of older formations.

While the sequence of events is not wholly clear, it seems probable that great folding, faulting, and metamorphism of all the rocks as yet referred to was the next great step in the history of the region. The gneisses and schists are penetrated by a large number of granite masses, one known important body of gabbro, and many small dikes of diabasic rocks. Some of these rocks cut the Uncompahgre strata, and the comparatively unaltered textural condition of these intrusives appears to indicate that they are all later than the time of the above-mentioned folding to which the Algonkian sediments were subjected.

The presence of occasional fragments of granite or schist in the igneous intrusives of the Rico or La Plata mountains shows that these same old formations exist beneath later rocks in the country west of the Animas.

Paleozoic history.—Before the earliest Paleozoic sediments of the region were deposited there was a period of enormous erosion which appears to have affected the southern Rocky Mountain province and probably large areas of contiguous country. A peneplain of marked character was produced, which, on sinking beneath the later Cambrian sea, became the floor for the deposition of the Ignacio quartzite. If that formation is of Saratogan (Upper Cambrian) age, as now believed, it is reasonable to refer this great erosion to earlier Cambrian time.

As will be clear from the description of the Paleozoic formations, the epochs of sedimentation during the Ordovician, Silurian, and Devonian periods must have been almost insignificant compared with the intervals of nondeposition. The latter, however, were certainly not times of continental uplift to any great elevation above sea level, in this province, a land surface near sea level, because the erosion of the interval was nowhere sufficient to wholly remove the Ouray limestone at any point observed on the southern slopes of the San Juan region. As stated in a preceding section the absence of the Ouray limestone in the valley of Silver Creek, near Rico, is supposed to be due to erosion of this interval. That is, however, the only point adjacent to the San Juan Mountains as yet found where the Ouray is lacking at its appropriate place in the section. It may be that the area of greatest elevation and consequent erosion, of the time in question, was west of the San Juan area, in what is now the plateau district.

The Pennsylvanian sedimentation was of very different character from any that preceded it in the general area of southwestern Colorado. A long-continued oscillatory movement of the earth's crust caused frequent recurrence of conditions favorable to the deposition of limestones, shales, and sandstones, forming the complex called the Hermosa formation. Without visible break the Hermosa beds grade into those of the Rico (Permo-Pennsylvanian) and those into the overlying Cutler red beds, here assigned to the Permian.

The character of the Cutler formation is in general much like that of the lower portion of the "Red Beds" in many other places where no stratigraphic break separates them from strata containing a Pennsylvanian fauna. The fact that a break is now known to exist above the Cutler beds renders it impossible to assume that the Paleozoic section of the San Juan region is complete. There may have been deposited in this district a considerable thickness of Permian strata now entirely absent, owing to the pre-Dolores erosion.

Pre-Dolores uplift and erosion.—The angular unconformity at Ouray between the Dolores and older formations testifies to important uplift affecting the entire known Paleozoic section. The geographic extent of this uplift remains to be determined. The Cutler beds were sharply folded in the Ouray district, but apparently the region of maximum disturbance lay to the north and east of the San Juan, since on the south and west no relations of marked unconformity exist between the Dolores and Cutler formations.

The epoch of uplift and consequent erosion under discussion was followed by the deposition of the fossiliferous Dolores strata, but until the horizon within the Triassic system represented by those beds has been determined it is premature to assign the orogenic movement to late Paleozoic rather than to early Mesozoic time.

Mesozoic history.—Evidence that the Dolores formation is of Triassic age has been given. In the upper Dolores Valley, as in the San Miguel to the north and the Animas to the east, the Triassic strata are overlain with apparent conformity by the La Plata formation, yet on the northern side of the San Juan the La Plata transgresses the edges of older sediments and in places rests on the Archean, demonstrating that a period of continental uplift and great erosion intervened between the Dolores and La Plata epochs. Similar relations are known elsewhere in Colorado.

Whatever decision may ultimately be reached as to the relations of the Gunnison group as a whole, it is true that the upper of the assumed Jurassic formations, the McElmo, bears such strong lithologic resemblance, in some of its upper sandstone members, to the Dakota sandstone of the Cretaceous that it would be natural to assume that both formations belong to one epoch of sedimentation, rather than that there was a great stratigraphic break between them, involving the whole of Lower Cretaceous time.

The Upper Cretaceous section formerly present in the Rico region was doubtless like that which has been mentioned as present south of the La Plata Mountains. The alternation of shales and

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Through the San Juan uplift a large area was elevated far above sea level and has never again sunk below it. Erosion became active and degradation of the land area continued until it was reduced to a peneplain, possibly with a small mountainous island rising above it to which the Needle Mountains area belonged. The peneplain in question is that upon which the Telluride conglomerate (Eocene?) rests in the western San Juan and San Miguel mountains.

That this post-Laramic peneplain extended over the Rico quadrangle is evident. The nearest point at which it can now be seen is beneath the Telluride conglomerate in Mount Wilson, about 5 miles north of the northeast corner of the Rico quadrangle, at an elevation of 12,000 feet. In Sheep Mountain, 6½ miles to the northeast, the same horizon is shown. The general position of this plane in the Telluride quadrangle is represented and its significance is discussed in the Telluride folio.

TERTIARY PERIOD.

No surface rocks of the Tertiary period now exist in the Rico quadrangle, but it is necessary to refer to rocks of that age which formerly covered the area, in order to discuss intelligently the history of the Rico Mountains.

ACCUMULATION OF THE TELLURIDE CONGLOMERATE.

When the peneplain produced by erosion following the post-Laramic uplift had reached a certain stage of development the local conditions changed, so that a great amount of débris from the ensuing further erosion of the adjacent mountain masses was deposited upon it as a conglomerate. This formation, originally called the San Miguel conglomerate and afterwards renamed the Telluride, acquired a rapidly increasing thickness westward from its border in the Silverton quadrangle to the San Miguel Mountains. On its border it is 50 feet or less thick and is a coarse conglomerate. In Mount Wilson, a few miles north of Rico, it is about 1000 feet thick and consists of fine conglomerate, sandstone, or shale, the transition in texture and thickness being clearly exhibited in the intermediate area.

While much of the Telluride formation is well stratified and apparently of subaqueous origin, it seems possible that the whole may have been of fluviatile origin. In any case it is probable that the conglomerate was deposited over the Rico area with a texture and thickness corresponding to that [illegible] San Miguel Mountains.

ters in a general way with similar occurrences of the San Juan area. Porphyritic diorite, monzonite, or granite intrusions are known in the Telluride and Silverton quadrangles, and in some cases proof exists that they are later than some of the surface volcanics. The epoch of intrusion is, however, not at all clearly determinable with reference to the general time scale. The stock eruptions of the Telluride and Silverton areas are later than any known lavas of those districts, and as the Rico and La Plata stocks cut the laccolithic intrusions of similar magmas, it may well be that all eruptions of this type can be referred to the same epoch in the latter part of the Tertiary.

It has been pointed out that the Rico Mountains belong to the laccolithic group of the Henry Mountains type, in spite of local structural features not commonly supposed to exist in some of the similar centers of intrusion. These general considerations as to the time of the Rico intrusions have undoubtedly a bearing on the question as to the age of all the laccolithic groups of the plateau province. The conclusion reached here is in accord with that derived from the examination of the Elk Mountains, Colorado (see Anthracite-Crested Butte folio).

UPLIFT OF THE RICO DOME.

It was brought out in describing the structure of the Rico dome that three elements enter into its constitution, namely, domal uplift by folding, igneous intrusion, and faulting. Whether or not these are all resultant phases of the action of one great force is a question of far-reaching importance. The evidence to be found in the Rico Mountains is manifestly inadequate for the solution of this problem. It is clear, however, that the various manifestations of deep-seated forces at this point belong to different epochs and seem in some particulars independent of each other.

Quaquaversal folding.—It is believed that the quaquaversal folding which seems to have been the principal factor in the elevation of the Rico dome took place after the accumulation of a considerable thickness of volcanic rocks from San Juan eruptions—that is, in the Tertiary period and possibly in the Eocene epoch soon after the formation of the San Juan tuff. The erosion which produced the Telluride peneplain would surely have truncated the dome had this structure been of Mesozoic age. That plain is, however, nowhere seen in the Rico Mountains, although Blackhawk Peak still rises more than 600 feet above the level at which it [illegible] known important body of gabbro, and many small dikes of diabasic rocks. Some of these rocks cut the Uncompahgre strata, and the comparatively unaltered textural condition of these intrusives appears to indicate that they are all later than the time of the above-mentioned folding to which the Algonkian sediments were subjected.

The presence of occasional fragments of granite or schist in the igneous intrusives of the Rico or La Plata mountains shows that these same old formations exist beneath later rocks in the country west of the Animas.

Paleozoic history.—Before the earliest Paleozoic sediments of the region were deposited there was a period of enormous erosion which appears to have affected the southern Rocky Mountain province and probably large areas of contiguous country. A peneplain of marked character was produced, which, on sinking beneath the later Cambrian sea, became the floor for the deposition of the Ignacio quartzite. If that formation is of Saratogan (Upper Cambrian) age, as now believed, it is reasonable to refer this great erosion to earlier Cambrian time.

As will be clear from the description of the Paleozoic formations, the epochs of sedimentation during the Ordovician, Silurian, and Devonian periods must have been almost insignificant compared with the intervals of nondeposition. The latter, however, were certainly not times of continental uplift to any great elevation above sea level, in this province at least, since the thin formations of the Ignacio, Elbert, and Ouray epochs, though separated by intervals representing long periods of land conditions, are preserved in almost conformable relations in the Animas Valley, a few miles east of the Rico quadrangle. A fuller discussion of this feature of Paleozoic history is given in the Needle Mountains folio.

Apparently the deposition of the Ouray limestone was continuous from late Devonian into early Carboniferous (Mississippian) time, and the succeeding elevation must have produced, as did the earlier of the fossiliferous Dolores strata, but until the horizon within the Triassic system represented by those beds has been determined it is premature to assign the orogenic movement to late Paleozoic rather than to early Mesozoic time.

Mesozoic history.—Evidence that the Dolores formation is of Triassic age has been given. In the upper Dolores Valley, as in the San Miguel to the north and the Animas to the east, the Triassic strata are overlain with apparent conformity by the La Plata formation, yet on the northern side of the San Juan the La Plata transgresses the edges of older sediments and in places rests on the Archean, demonstrating that a period of continental uplift and great erosion intervened between the Dolores and La Plata epochs. Similar relations are known elsewhere in Colorado.

Whatever decision may ultimately be reached as to the relations of the Gunnison group as a whole, it is true that the upper of the assumed Jurassic formations, the McElmo, bears such strong lithologic resemblance, in some of its upper sandstone members, to the Dakota sandstone of the Cretaceous that it would be natural to assume that both formations belong to one epoch of sedimentation, rather than that there was a great stratigraphic break between them, involving the whole of Lower Cretaceous time.

The Upper Cretaceous section formerly present in the Rico region was doubtless like that which has been mentioned as present south of the La Plata Mountains. The alternation of shales and sandstones, with numerous coal beds, testifies to general conditions similar to those prevailing in the Rocky Mountain province, but differing somewhat in detail.

Post-Laramie uplift and erosion.—That the domal folding of the entire Paleozoic and Mesozoic section about the San Juan center occurred in the interval succeeding the Laramie epoch has been clearly established and is discussed at some length in the Telluride folio. The local uplifts of the Rico and La Plata mountains are imposed upon that older structure and to some extent obscure it. fluviatile origin. In any case it is probable that the conglomerate was deposited over the Rico area with a texture and thickness corresponding to that exhibited in the San Miguel Mountains.

No fossils have been found in the Telluride formation, hence its exact age is unknown. Its relation to the San Juan volcanic deposits shows it to have immediately preceded them and at present it is assumed to be of early Eocene age, although there are some reasons for thinking that the Telluride conglomerate may be correlated with the Arapahoe formation of the Denver region, assigned to the Post-Laramie part of the Cretaceous on paleontologic evidence. A full discussion of this question is given in the Telluride and Silverton folios.

SAN JUAN VOLCANIC ERUPTIONS.

The volcanic complex of the San Juan region is known to be the result of outbursts of various kinds and with various products, extending through Tertiary time. The earliest eruptions must have followed the deposition of the Tel ride conglomerate very closely, and it is probable, . m the considerable thickness of tuffs and lava . ws above that formation still remaining in the adj. nt San *Miguel and San Juan mountains, that the* lower volcanics extended over the Rico area, with a thickness perhaps of several thousand feet. This question is particularly referred to in the Telluride folio, while the explanation of the absence of the volcanics in the Rico summits is presented below, in the discussion of the origin of the Rico domal uplift.

IGNEOUS INTRUSIONS OF THE RICO AND LA PLATA MOUNTAINS.

While no surface volcanics are now preserved in the Rico quadrangle, the numerous intrusive rocks which have been described belong undoubtedly to the Tertiary period. It is, indeed, possible that the monzonite or syenite stocks of the Rico and La Plata centers may represent channels through which extensive outpourings of lava took place. Be that as it may, there is every reason to correlate the igneous phenomena of these local centers [illegible] age. That plain is, however, nowhere seen in the Rico Mountains, although Blackhawk Peak still rises more than 600 feet above the level at which it *appears in Mount Wilson, a few miles to the north.*

The greater part of the uplift which has taken place has affected the whole Paleozoic section and the underlying Algonkian rocks and thus the small Rico dome comes to show close relationship with the much broader San Juan uplift. As has been stated already, the most prominent structure in the San Juan region is pre-Tertiary in origin, but there was also uplift in Tertiary time, and it is possible that the Rico dome is synchronous with the later elevation and a result of the same force. The same is true of the La Plata Mountains. But until the structural history of the San Juan region has been studied in much greater detail the relation between the local uplift of the Rico and La Plata mountains and the more nearly continental movements of the San Juan region can not be thoroughly discussed.

Age of the laccolithic intrusions.—The dikes, sheets, and small laccoliths of porphyry in the Rico Mountains belong to the group of diorite-, monzonite-, and granite-porphyries which are so widespread in the laccolithic mountain groups of the plateau country and also in the mountains of Colorado. That these rocks are in all these instances of approximately the same age is a natural conclusion in harmony with all known facts, although the definite evidence of Tertiary age is found in but few localities.

Evidence at Rico bearing on this question is limited to the general considerations above stated as to the age of the domal uplift. In the adjacent Telluride and Engineer Mountain quadrangles there are large laccolithic bodies of porphyries very similar to rocks of the Rico Mountains, and some of these are intruded into volcanic rocks, proving their Tertiary age. But no evidence has been found to indicate the particular epoch of this period in which the intrusions took place.

Stock eruptions and faulting.—In considering the nature of the forces which have produced the Rico uplift, it is apparent that there is a close analogy between the two phases of intrusive action and the two phases of structural uplift. The primary upward pressure at this center was one to which the whole section of Paleozoic and Mesozoic strata accommodated itself by folding, stretching, and no doubt by minor fissuring. It would appear to have been a gradually exerted pressure, of the kind assumed to have forced the magmas of laccoliths and analogous sheets between the strata of a sedimentary complex. Corresponding to this idea, it is found that the distinct porphyry sheets of the Rico Mountains are the earliest intrusions.

The fault blocks of the heart of the mountains, made up, at the exposures now seen, of Algonkian schists and quartzites, have been thrust up through the folded strata with little or no evidence of contemporaneous folding of the adjoining beds. This is also the relation of the Darling Ridge monzonite stock, as far as can be seen, and also of the similar stocks of the La Plata, Telluride, and other neighboring quadrangles. Such fault blocks and such masses of igneous rocks seem alike due to forces suddenly exerted, producing vertical fracture instead of doming. With such an analogy in mind, the suggestion naturally arises that a mass of magma, forming a stock in greater depth, may have followed the upthrust blocks now revealed. Such a hypothesis requires the assumption of very direct connection between the propelling forces of magmas and those of structural uplift.

Connection between folding and intrusion.—If folding and intrusion at the Rico center be referred to the action of the same great force, it is difficult to explain why larger amounts of magma were not intruded into the strata of the Rico dome, in view of the large porphyry masses of probably contemporaneous origin occurring near at hand in comparatively undisturbed beds. The Flattop mass of porphyry, exceeding in bulk all the sheets of the Rico Mountains put together, occurs just at the northeast base of the dome, but similar large bodies occur on the San Miguel River in the Telluride quadrangle, 20 miles from the Rico uplift, and another occurs in Hermosa Peak, a few miles to the east. The stocks of the Telluride quadrangle appear likewise to be distributed without visible relation to any structure of the sedimentary formations. In other words, it appears to be the case that, while laccolithic intrusions and stock eruptions have occurred at the Rico and La Plata centers, both forms of intrusion have also taken place not far away in much greater volume, at points seemingly independent of such centers. It is to be hoped that more extended studies of the San Juan and adjacent regions may throw light on the relations of these various phases of intrusion of magmas to structural movements of the earth.

PHENOMENA CONNECTED WITH IGNEOUS INTRUSION.

Aside from the mechanical features of intrusion, which have been referred to, the principal phenomena connected with the igneous intrusions of the Rico Mountains are those of contemporaneous metamorphism and of solfataric exhalation which appears to have continued down to the present time.

Contact metamorphism.—Contact metamorphism of the calcareous strata adjacent to the monzonite stock is very pronounced at nearly all places where these rocks are exposed in the vicinity of the intrusive. The character of the alteration is such as might be expected from the action of mineralizing agents, as chlorine, fluorine, and heated water carrying those gases and perhaps others in solution. The metamorphism referred to consists in the formation of garnet, pyroxene, vesuvianite (?), and possibly other silicates of alumina, with magnesia, iron, and lime, and in the deposition of specular iron in scales, either impregnating the rocks or more commonly in thin seams in-sion. The eastern end of the monzonite is just above the street in Piedmont, and there must have been fissures traversing the strata in the prolongation of the principal axis of the stock. These may have given heated solutions the necessary access to the limestone at the places now seen. So far as observed, such contact metamorphism is confined to the zone about the stock, with the exception of one place in the shattered zone, between the forks of the Blackhawk fault, where garnet masses and specular iron occur near a small porphyry dike.

Solfataric action.—While no evidence can ever be discovered proving that the surface phenomena ordinarily known as volcanic attended the deep-seated intrusions in the Rico dome, certain processes which are generally supposed to characterize zones near the surface have been active in the horizons now revealed by erosion. One of these processes is the decomposition of rocks by sulphurous vapors or by solutions that have absorbed those vapors, and the production of alunite. This substance is formed at the surface in the crater of Solfatara, near Naples, and is a common product of the sulphurous emanations of volcanoes known from this locality as solfataric exhalations. But the process is not necessarily connected with solfataras of typical volcanoes, and the term has been gradually extended to cover the metamorphosing action often consequent on eruptions which have been accompanied by mineralizing agents of sulphurous character, even when taking place in depth.

The orthoclase-bearing porphyry mass of Calico Peak has been almost wholly decomposed by such agents, alunite and kaolin being the principal products.

Existing sulphur springs.—It is especially noteworthy, in connection with the evidence above given of former intense solfataric action, that there are numerous springs of water heavily charged with sulphureted hydrogen issuing to-day from the slopes of Stoner and Johnny Bull creeks and of other tributaries of the West Dolores north of Johnny Bull Creek. The waters of these springs are surface waters, as they are influenced directly by the rainfall of the season and dry up at times, but the sulphurous gases escape continuously. The exclusive presence of these springs on the west side of the dome, extending from the immediate vicinity of the solfataric center at Calico Peak toward the West Dolores, suggests that these exhalations really belong to a later solfataric period of this eruptive center.

ORE DEPOSITION.

After the uplift of the Rico dome, the intrusion of the igneous rocks, and at least a portion of the fault fissuring there was a period of extensive ore deposition in the rocks now forming the Rico Mountains. While the age of the ore deposits can not be closely determined, it is in every way probable that they correspond in time to the deposits of the La Plata Mountains and that they belong to the great epoch of ore deposition which succeeded the early Tertiary igneous intrusions or more typical volcanic eruptions in many parts of the Rocky Mountains. Apparently the more typical laccolithic mountain groups of the plateau country to the west do not contain ore deposits in an abundance at all corresponding to their development in the La Plata and Rico mountains, but whether that fact is connected with their situation remote from the great centers of eruptive activity or with local causes can not now be determined. It would, however, appear natural that more extensive deposition of ore minerals should occur in a center like the Rico Mountains, where there has been so unusual an amount of fissuring, affording channels for the circulation of metal-bearing solutions.

EROSION OF THE RICO DOME.

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question. Naturally the work of distinct epochs of Tertiary erosion can not be recognized in the Rico district, and the present discussion is, therefore, directed to the local problem as to the sculpturing of the Rico dome. This erosion began with the rise of the dome, at some unknown time in the Tertiary period, and has continued to the present day, although discussion is here confined to pre-Glacial erosion. The glaciation here referred to is that of which evidence is observable, and is not necessarily the earliest of the region, as will be explained in a later paragraph.

Sculpturing of the dome.—At the inception of the Rico dome the volcanic rocks which covered the San Juan country were being attacked on all sides by streams whose positions were probably determined by the distribution of the volcanic materials. So long as eruption continued the stream courses were constantly liable to alteration by lava flows, but with the temporary cessation of volcanic activity each stream would maintain the course it then held, deepening its channel and sapping at its head to extend its canyon into the central mountainous region. It seems probable that the Dolores River had assumed its present course previous to the formation of the Rico dome, since, supposing that the surface at the time the dome was formed was sufficiently smooth for the development of consequent drainage on its slopes, it is difficult to understand how one of the radial streams thus resulting could have gained so distinct an advantage over the others that it would finally cause their complete diversion. The relations of hard and soft rocks in the region to the north of the dome are such that it seems as if diversion of the radial streams on the northern slope must have been accomplished by the western branch of the Dolores River long before any stream originating on the southern slope of the Rico dome could have cut its valley backward through the hard core of the group to the north side of the dome structure.

The actual amount of erosion since the Rico uplift can not be estimated, since its effects are not separable from those of the epoch preceding. It is believed, however, that the volcanic rocks had not been removed entirely and that, as in Mount Wilson, to the north, sediments above those now exposed were present, up into the Mancos shale, at the time of uplift.

Whether the Dolores was flowing in . . .

The monzonite stock on the west side of . . . river has been sufficiently resistant to form a . . . both south of Aztec Gulch and in the main di. . . south of Horse Gulch, though in neither place . . . it reach to as high an elevation as the porphy. . . of the adjacent peaks.

The distribution of the laccolithic porphy. . . masses in the upper part of the Dolores forma. . . has determined the zonal grouping of the princ. . . mountain peaks about the center of the dome st. . . ture. In fact, it is to these porphyries tha. . . Rico Mountains owe their existence. Had . . . not been encountered by the streams, the . . . in dissecting would have given to the dom. . . molding scarcely different from that which . . . have impressed upon the adjacent areas of se. . . mentary rocks; the concentric outcrops of . . . harder beds would be expressed in knolls . . . curving ridges, but the general elevation w. . . have been much less than at present.

GLACIATION OF THE RICO MOUNTAINS.

It is known that the higher portions of the . . . Juan region were practically covered by an . . . sheet during a late stage of the Glacial epoch. . . It is, therefore, not strange to find eviden. . . of recent local glaciers in the Rico Mountains. . . Reasons exist for believing that the San Ju. . . Mountains were also glaciated in an earlier . . . tion of the Glacial epoch, but evidence bea. . . on this question is found in the Rico dis. . . only in certain high-level gravels of the Dolo. . . Valley.

Evidence of recent glaciation.—The record . . . glaciers in the Rico Mountains is seen in cer. . . topographic forms, in rock scoring, and in ac. . . mulations of débris, but none of these is strikingly . . . prominent or characteristic, from which it appe. . . that because of their somewhat lower altitude a. . . their isolation the Rico Mountains were not . . . completely dominated by the ice as were the . . . higher mountains adjacent. They formed a lo. . . center of accumulation, and though the basins . . . Rico were probably deeply buried in snow the. . . were but few places in which the accumulatio. . . became sufficiently deep for the consolidation of . . . the snow into true glacial ice.

That glaciers were not prominent for any grea. . . length of time seems clear from the absence of . . . marked glacial cirques or amphitheaters in the . . .

angle appear likewise to be distributed without visible relation to any structure of the sedimentary formations. In other words, it appears to be the case that, while laccolithic intrusions and stock eruptions have occurred at the Rico and La Plata centers, both forms of intrusion have also taken place not far away in much greater volume, at points seemingly independent of such centers. It is to be hoped that more extended studies of the San Juan and adjacent regions may throw light on the relations of these various phases of intrusion of magmas to structural movements of the earth.

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Contact metamorphism.—Contact metamorphism of the calcareous strata adjacent to the monzonite stock is very pronounced at nearly all places where these rocks are exposed in the vicinity of the intrusive. The character of the alteration is such as might be expected from the action of mineralizing agents, as chlorine, fluorine, and heated water carrying those gases and perhaps others in solution. The metamorphism referred to consists in the formation of garnet, pyroxene, vesuvianite (?), and possibly other silicates of alumina, with magnesia, iron, and lime, and in the deposition of specular iron in scales, either impregnating the rocks or, more commonly, in thin crusts in fissures. Such alteration of the calcareous strata may be seen on the north side of Darling Ridge, near the blowout in Horse Gulch, and down near Piedmont. If the metamorphosed stratum is a limestone the matrix for the silicates named is usually white crystalline marble.

The great metamorphism of the Devonian limestone in the Dolores Valley at Rico is so clearly of *the kind described that it is considered probable* that this change is also due to the monzonite intru-

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EROSION OF THE RICO DOME.

General statement.—The San Juan and adjacent country appears to have been a continental tract during the whole of Tertiary time. Erosion must, therefore, have been continually in progress during that period. The work of degradation was repeatedly interrupted and in great measure undone by vast volcanic accumulations in several different epochs. Further, the erosive power of streams varied greatly, according to the alter*nating elevation or subsidence of the region,* which probably continued during the period in

exposed were present, up into the Mancos shale, at the time of uplift.

Whether the Dolores was flowing in a shallow valley or deep canyon previous to the domal uplift at Rico can not be surmised, but before the completion of the structure the stream had doubtless cut a deep trench well down toward the base of the volcanic rocks which are supposed to have covered the region, and possibly into the Mesozoic sedimentary rocks, upon which they probably rested. This erosion belonged to the epoch of deformation. It was succeeded by continued erosion of the present epoch as arbitrarily limited by the completion of the distinct uplift.

With the downward cutting there has doubtless been concomitant elevation, but of this there is no evidence in the immediate vicinity of Rico, though some 16 miles or so to the south there are gravel *beds about 400 feet above the present valley floor,* showing the former position of the stream bed and indicating an uplift since their deposition. The effect of erosion within the mountains has been as if the river had cut its way at once to the present position and then side streams and gullies had completed the grading of the slopes. It is believed, however, that several distinct uplifts have occurred, but the pauses between them left no records because of the fact that the river was cutting its channel and not at any time widening its valley, so that the valley was successively deepened, and under conditions of heavy precipitation the slopes of the valley walls were gradually reduced without the production of terraces.

The softer rocks have been carved away, leaving the more indurate as cliffs or steep slopes between more gentle acclivities and determining the positions of the main mountain masses. The rocks which have been sufficiently massive to form mountain caps are mostly intruded porphyries, though the La Plata sandstone always rises as a knob above the general level of the adjacent ridges. Of the few high peaks capped by other sediments than La Plata, Telescope Mountain is the only one *not protected by a very massive sheet of porphyry* lying within 100 to 200 feet of the top.

length of time seems clear from the absence of marked glacial cirques or amphitheaters in the higher mountains. The basin at the head of the small gulch next east of Allyn Gulch, in the eastern part of the group, is the only one of the region which strongly resembles a typical cirque. It is also noteworthy that the side gulches of the mountains seldom possess the profile outline characteristic of valleys filled by glaciers, the only two exhibiting the U-shaped form being Silver and Horse gulches, the largest and deepest of the group.

Striated or grooved rock faces have been noted in several places, notably in Deadwood and Silver gulches and near the head of Johnny Bull Creek, west of Calico Peak.

Glacial débris retains distinct morainal form only on the southeastern slopes of the mountains, at the head of two branches of Scotch Creek, in *the Engineer Mountain quadrangle.* These were deposited by short glaciers of small dimensions. In other places the gravels supposed to be of glacial origin are mingled with avalanche, landslide, or wash débris, and could not be shown on the map. They occur on various ridges or mountain slopes and in certain gulches, and details of their observed distribution were given in the Rico report.

The rounded ridge at the entrance to the valley of Silver Creek has an external appearance similar to that of kames or eskers, but it is really composed of sedimentary rocks and intrusive porphyry and is merely capped by gravels. It is consequently a form of erosion rather than of construction.

Collectively the phenomena observed are believed to warrant the conclusion that true glacial streams at one time existed on the southeastern slopes of the mountains, in the valley of Silver Creek and its tributaries, and in Deadwood Gulch, and that in the upper part of Horse Gulch there were important accumulations of ice which may or may not have reached into the lower part of the valley. If others existed, their marks have been *obscured by surface materials of another origin* or by recent erosion.

Valley gravels related to glacial deposits.—A group of gravel deposits which may be tentatively referred to the close of the recent (Wisconsin) stage of glaciation occurs in the Dolores Valley at many points from the Rico Mountains downward. These gravels are seen in the terrace upon which the town of Rico is partly built, and on the similar and probably corresponding bench which occurs about 40 or 50 feet above the river bed north of the mouth of Sulphur Creek. The gravels are best exposed in the cutting for the roadway to the railroad station at Rico, but are known to form the edge of the terrace for nearly half a mile to the south. Occasional remnants of corresponding gravel benches occur down the Dolores River as far as the mouth of Bear Creek. South from Montelores the bench is from 10 to 30 feet above the present stream, and it seems to slope down the valley at a slightly greater grade than that of the Dolores River. This bench is not entirely depositional, since occasional exposures show rock in place. Just north of the mouth of Ryman Creek the inclined and truncated edges of the Cutler beds are shown to be covered by a thin capping of gravel, and east of Montelores the eroded surface of the porphyry is but partially concealed.

Less conspicuous remnants of a gravel terrace occur along the Bear Creek flat. This terrace is at about the same elevation above the present stream as the Dolores terrace and seems to be closely related to it genetically. At the angle of the union of the streams a terrace remnant appears to be common to both. The terrace gravels of Bear Creek came, of course, from the La Plata Mountains. West of the mouth of Bear Creek this bench is inconspicuous or wanting. It seems probable that these Dolores Valley gravels represent the scanty morainal materials of the Rico glaciers transported and deposited. The amount of stream cutting below the gravel-covered terraces is consistent with this idea.

Ancient glacial (?) gravels.—Coarse gravel or bowlder beds, which from their position suggest a considerable former extent of such materials, occur at numerous points in the Dolores Valley at several hundred feet above the present stream. The most northerly of these observed occurrences is on the ridge south of Aztec Gulch, near Rico, where, at an elevation of 9500 feet, or about 700 feet above the river, an excavation in the wooded surface reveals a mass of very round bowlders lying in fine gravel. Among the rocks represented are blue limestone, greenish sandstone, and vein quartz. The bowlders are very unlike the angular fragments which are sparingly scattered about the surface. These angular blocks, often 3 feet or more in diameter, seem to have come from up the river, for red Dolores sandstone is common among them. Bowlder gravels have also been exposed at a lower level on this same ridge in prospects near the line of the Calumet vein, about 300 feet above the river.

On the slope below the tufa bench south of Sulphur Creek, southwest of Rico, at about 300 feet above the river, there are several patches of coarse gravel beds. Among the fragments noticed here was one block, nearly 3 feet in diameter, of the peculiar hornblendic porphyry known only in dikes in the Algonkian schists above Rico.

Further down the Dolores Valley other similar gravel patches occur at this general level of 300 feet above the river. They are especially well shown on the west side of the river between Snyder's ranch and Rio Lado and have been noted also near the mouth of Bear Creek. Possibly they occur in small remnants much farther down the river. A specially good exposure was noted near the mouth of Tenderfoot Creek, where the pebbles average about 4 or 5 inches in diameter, character of the bowlders and the meager evidence concerning their origin scarcely warrants the assumption of any particular relation to more ancient glaciation. Gravels of high level are abundant on all sides of the San Juan, and in the forthcoming Ouray folio strong evidence indicating a pre-Wisconsin glaciation will be given.

LANDSLIDES.

The landslide areas of the Rico Mountains, which assume unusual importance, have been described as to their character and local distribution, and it remains to refer briefly to their age and the evidence of their origin. A much fuller treatment of the subject is given in the Rico report.

Age of the landslides.—The epoch of the Rico landslides may be said to extend backward from the present day to their beginning, at a remote period not accurately determinable. From the great number of the slides in this limited region and the conditions of their distribution it must be assumed that they are primarily due to some very unusual force, shattering the rocks to a remarkable degree and principally exerted at the beginning of the landslide epoch. It is therefore of prime interest to ascertain when these slides began.

Of all the phenomena of Quaternary age in this region there is none affording definite proof as to the remoteness of the time at which the fracturing of the formations took place. The principal changes in the topography since the landslides began have been caused by the slides themselves. There has been practically no erosion in the Dolores Valley or in the more evenly graded reaches of its local tributaries in the landslide epoch. All the distinct alluvial formations, as flood plains and the fans or aprons at the mouths of streams tributary to the Dolores, are referable to activities during the landslide epoch. Even the glacial deposits seem to afford little evidence as to the age of the first landslides. The main traces of glacial deposits are in the eastern portion of the Rico Mountains, where landslides have not occurred; and the gravel deposits, which seem to be of glacial origin, have in most cases been more or less rearranged, so that little weight can be placed on conclusions drawn from their present position. The landslide period was apparently contemporaneous with the glaciation, or nearly so.

Relations to topography.—From the details regarding the various slide areas which have already been given and from the illustrations, it is evident that the topography of the Rico Mountains had acquired almost the detail it now exhibits when the landslides began. The only considerable modification of that topography in the intervening time to the present has come directly from the landslides or indirectly through the rapid breaking down of the principal slide areas. The valley of the Dolores, at the foot of C. H. C. Hill, must have been of the exact type now seen above Marguerite Draw. The stream bed of Horse Creek has plainly been interrupted by the Puzzle slide.

The primary conditions for a landslide may be generally stated as a thoroughly fractured state of the rocks on steep slopes, permitting the force of gravity to cause the fall; and were all the rocks of a mountain district to be uniformly shattered the mountains of most precipitous and irregular form would naturally experience the most extensive landslide action. But in the Rico district some of the most rugged mountains have undergone no visible degradation by landslips, even in the heart of the area most affected. Sandstone Mountain is the most striking instance of this immunity.

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One effect of this saturation by circulating waters has been to keep the fracture lines of attrition matter and many layers of crushed sandy shale in a soft condition, favorable to the slipping of more or less extensive masses whenever the support weakened sufficiently. Secondary slides of this sort must have been frequent ever since the original shattering of the formations, and they are still taking place.

The more exposed and isolated landslide blocks, *if prevented from further slipping en masse, break* up gradually, while a talus slope or an avalanche track often denotes the course of the more rapid disintegration.

Origin of the landslides.—The immediate cause of the Rico landslides is manifestly the very unusually shattered condition of the rock formations on steep slopes, and the discussion of origin must be directed to the seat and nature of the force to which the intense shattering is due. The evidence concerning this force contained in the observations which have been recorded may be summarized as follows:

1. *The principal landslides are confined to a* small circular area in the heart of the Rico uplift, but do not cover all of that area.

2. The slides are more recent than the topographic details of the mountains and valleys, except only some recent and minor features.

3. The shattering of the rock varies locally in degree.

4. The shattering is independent of lithologic character and structural attitude of the formation, and there is nothing in either of these conditions especially favorable to landslides.

5. The principal landslide slopes are in the courses *of many known faults, but several intensely* faulted areas of rugged topography do not exhibit landslides.

6. Many fault veins seem to have been opened again by the shock producing the shattering of the formations.

7. The shattering extends below the surface zone of actual sliding and to unknown depths.

The consideration of all observed *facts* leads to the comprehensive statement that in *geologically* very recent time a part of the central portion of the Rico Mountains suffered a severe shock, shattering the rocks at the surface and to unknown depths. As a result of this shattering many landslides have occurred where other conditions were favorable. This shock must have had its source

at an elevation of 700 feet above the Dolores River on the northern edge of the monzonite arm from Darling Ridge are of Glacial origin, they indicate a much greater accumulation of such débris in the valley than would be suggested by any other occurrences. But even if they are Glacial, the recent work of the river seems to have been largely the removal of the gravels, with little cutting into the underlying rock. In Deadwood and Allyn gulches the streams have cut down through the unconsolidated gravels of Glacial origin, but this is a task which they could have easily accomplished in a *short time. Similar indications of the small effect* of post-Glacial bed-rock erosion are seen in Silver Creek, where the stream has locally excavated narrow canyons in the wider valley of Glacial origin, but these canyons have in no instance exposed the bed rock to a depth of more than possibly 20 feet, and in many places the stream is working on débris of very recent origin, which has been thrown into its channel from the side gulches and ravines. All the evidence serves to point to the recency of the Glacial occupation and to the small amount of erosion which has since ensued. The present topography is in no essential feature different from *what it was previous to the accumulation of the* ice. Before that the streams had found their present courses and had practically assumed their present grades.

In the higher parts of the mountains, however, the ordinary atmospheric agencies have been active and large amounts of talus and slide rock are seen on many of the steeper slopes.

Modification of topography by deposition.—The greatest change in the topography of the region since the great erosion has been effected through the agency of landslides. Throughout the larger tracts which are shown on the map the landslides *have modified the form of the ridges and* mountain slopes and have to some degree filled up the valley bottoms, especially of the Dolores opposite C. H. C. Hill and of Horse Creek. Apparently the streams in their lower courses have not as yet been able entirely to remove this landslide débris.

In the valley of the Dolores there are various *deposits of stream gravels, and the map shows the* distribution of the more recent deposits. Remnants of terraces in several places indicate former deposits, but these are not always clearly distinguishable from débris of other origin.

While the lateral tributaries of the Dolores have no bottom deposits of importance, several of them have built up very decided alluvial cones at their where, at an elevation of 9500 feet, or about 700 feet above the river, an excavation in the wooded surface reveals a mass of very round bowlders lying in fine gravel. Among the rocks represented are blue limestone, greenish sandstone, and vein quartz. The bowlders are very unlike the angular fragments which are sparingly scattered about the surface. These angular blocks, often 3 feet or more in diameter, seem to have come from up the river, for red Dolores sandstone is common among them. Bowlder gravels have also been exposed at a lower level on this same ridge in prospects near the line of the Calumet vein, about 300 feet above the river.

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These high-level bowlder beds are considered as mere remnants of important deposits belonging to the epoch when the floor of the valley was 300 feet or more above its present stream bed. From the evidence, common in southwestern Colorado, of slight stream erosion since the last Glacial epoch, it would seem necessary to conclude that the gravels under discussion are older than the recent (Wisconsin) stage of glaciation. But the waterworn position. The landslide period was apparently contemporaneous with the glaciation, or nearly so.

Relations to topography.—From the details regarding the various slide areas which have already been given and from the illustrations, it is evident that the topography of the Rico Mountains had acquired almost the detail it now exhibits when the landslides began. The only considerable modification of that topography in the intervening time to the present has come directly from the landslides or indirectly through the rapid breaking down of the principal slide areas. The valley of the Dolores, at the foot of C. H. C. Hill, must have been of the exact type now seen above Marguerite Draw. The stream bed of Horse Creek has plainly been interrupted by the Puzzle slide.

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Relations to other Quaternary phenomena.—The ordinary processes of degradation operative in the high mountain regions of Colorado have of course been active in the Rico Mountains during the long epoch of landslide action, and it scarcely need be pointed out that all the destructive agencies must have been especially effective within the landslide areas. The shattered landslip blocks themselves have been in high degree vulnerable to the attacks of solvent waters, frost, etc., and have in many cases rapidly disintegrated. The whole slope of Darling Ridge, as of other landslide areas, is practically without surface drainage channels, so the Rico Mountains suffered a severe shock, shattering the rocks at the surface and to unknown depths. As a result of this shattering many landslides have occurred where other conditions were favorable. This shock must have had its source in greater or less depth, and may be referred to as earthquake shock.

Two important sources of earthquake shock are specially recognized, viz, that originating in the relief of tension arising from structural movements of the earth's crust, and that connected with volcanic phenomena. The Rico Mountains represent a center of upheaval and intense faulting, and of igneous intrusions of a nature not strictly volcanic. It seems natural to suppose that seismic disturbances must have taken place at the surface of the Rico dome during the periods of faulting and during the intrusion of at least the monzonite magma in the channels represented by the stocks of to-day. But those disturbances took place at so distant an epoch that the connection of the shocks now under discussion with either of them is not plausible.

RECENT GEOLOGICAL HISTORY.

Many of the features of post-Glacial geology at Rico are inseparable in origin from similar features of Glacial and earlier time, since in those parts of the area that were not covered by ice similar processes of general erosion and of local deposition were active throughout the Glacial stage. For this reason, in referring to certain phenomena as Recent, there is no intention of limiting their age to the post-Glacial, but rather to indicate that certain conditions have continued down to the present time. The Recent phenomena of the Rico region are mainly erosion and deposition. The latter includes landslides, talus, and avalanche materials, river gravels, and spring deposits, which have been described as formations. The processes of their formation are so commonly known that but little further reference to them seems necessary.

Post-Glacial erosion.—If the gravels occurring deposits, but these are not always clearly distinguishable from débris of other origin.

While the lateral tributaries of the Dolores have no bottom deposits of importance, several of them have built up very decided alluvial cones at their mouths. The more important of these are represented on the map.

Small deposits of calcareous sinter or tufa have been noted at various points on the banks of the Dolores, and several of them are shown on the map. At a number of these points the spring waters are still highly charged with carbonate of lime and deposition is still going on.

It will be noted that the effect of nearly all of these recent agencies is to modify the form of the mountains existing before the Glacial epoch and the beginning of the landslides, by producing gentler forms of the ridges and by filling up in some degree the various valleys.

Gas springs.—Emanations of carbonic acid gas and of sulphureted hydrogen accompany many springs of water in the Rico region. The former is continually escaping in large quantities in the central part of the area, while the latter is noted in many places on the west side of the mountain group in the drainage of Stoner and Johnny Bull creeks. Both gases doubtless have their origin in chemical changes which are going on at a greater or less depth beneath the surface, and the waters with which they are associated may or may not be of deep-seated origin. In some cases they certainly are not, for at the sulphur springs the water increases and diminishes with the humidity or dryness of the season, and at certain times the flow of water ceases entirely, while the gas continues to escape. It appears that in such instances the gases have found the same channels along which the waters are circulating and that the two mix and escape together. In the section on "Economic geology" Mr. Ransome tells of the frequent appearance of carbonic acid gas in mine workings.

June, 1904.

ECONOMIC GEOLOGY OF THE QU

By F. L. Ransome.

INTRODUCTION.

The principal ore deposits of the Rico quadrangle are confined to its northeast corner, and are included within the area of about 35 square miles covered by the Rico special map. The mining district is nearly coextensive with the isolated group of peaks which have been described in the foregoing pages as the Rico Mountains. Rico, a town of a few hundred inhabitants and the seat of Dolores County, lies nearly in the center of the district, on the Dolores River, which traverses the area from north to south. The Rio Grande Southern Railway connects the town with the Denver and Rio Grande system at Durango on the south and at Ridgeway on the north.

The following general account of the ore deposits is for the most part condensed from a report entitled "The Ore Deposits of the Rico Mountains, Colorado," published in the Twenty-second Annual Report of this Survey in 1902. To that report the reader is referred for detailed descriptions of individual mines.

HISTORY OF MINING DEVELOPMENT.

Records of the discovery and early development of the Rico ore deposits are fragmentary and often conflicting. The first recorded attempt to prospect the region was in 1861, when Lieutenant Howard and other members of John Baker's expedition into the San Juan region made their way over the mountains from the east. Eight years later Shafer and Fearheiler built a cabin on Silver Creek, near its junction with the Dolores River, and located several claims. One of these, the Pioneer, subsequently gave its name to the mining district.

In 1872 R. C. Darling and others erected an adobe furnace and attempted to smelt ores from what are now known as the Atlantic Cable, Aztec, Phoenix, and Yellow Jacket claims. They were unsuccessful, and it was not until 1877 that active prospecting was resumed in the Pioneer district.

In 1879 rich oxidized silver ore was discovered on Nigger Baby Hill, and the future productivity of Newman Hill was foreshadowed by the shipment to Swansea of some ore from the Chestnut vein. The town of Rico at once sprung into existence.

In October, 1887, the largest and richest of the blanket deposits on Newman Hill was discovered by David Swickhimer in the Enterprise shaft, at a depth of 262 feet, and shortly after ore bodies were found in the Blackhawk, Logan, and Rico-Aspen mines.

The Enterprise mine was sold in 1890 to a Pittsburg company, and the same year saw the advent of the Rio Grande Southern Railway. Vigorous exploitation was continued in various parts of the district until 1895, when mining activity showed signs of abating.

Since 1895 the output of the Pioneer district has decreased. The large bodies of rich "contact" ore have been mined out, and many of the veins have been worked down to a depth at which the ore no longer pays for shipment. Masses of ore often proved to be curiously limited, owing to various conditions that are characteristic of the region and that will presently be described.

The decline in the price of silver has had a depressing effect on this as on other districts where this metal forms a large part of the output. [illegible] all the important ore bodies formerly [illegible] Cable mine and to the experimental treatment of the sphaleritic ore there found.

PRODUCTION.

The total production of the Pioneer mining district can be only roughly estimated. According to the reports of the Director of the Mint, the output from 1879 to the end of 1903 has been about 75,000 ounces of gold and 9,000,000 ounces of silver. The value of the entire product, including the base metals, probably lies somewhere between $8,000,000 and $10,000,000. By far the greater part of this has been silver. Present developments indicate that the district may soon produce considerable zinc and lead.

PRELIMINARY OUTLINE OF THE ORE DEPOSITS.

The ores of the Rico district show unusual variety in their occurrence, as regards both form and genesis. It is proposed in this report to treat the deposits under four general heads, namely: (1) Lodes, (2) blankets, (3) replacements in limestone, and (4) stocks. This is confessedly and obviously a rough grouping for convenience and clearness of treatment, and is not intended as a scientific classification.

Under the first head will be described simple or complex veins, usually nearly vertical, which when they occur in the sedimentary formations cut across the planes of bedding. They are fractures or fissures in the rocks, which have been afterwards filled with ore or valueless vein matter.

Under the second head will be treated various deposits usually more nearly horizontal than vertical, and lying parallel to the planes of bedding or to the surfaces of intruded sheets of igneous rock. These are the deposits locally known as "contacts." This term, used in a sense that has no necessary connection with its true geological meaning, has unfortunately found its way into literature and has been so universally adopted by the miners that it is difficult to altogether avoid its use. Wherever employed, however, the word will be placed in quotation marks, indicating its true standing as miners' vernacular.

Under the third head will be considered those deposits, often irregular in form, which have resulted from the metasomatic replacement of limestone by ore.

Lastly, under the fourth head, will be noticed a few small ore bodies, often referred to as "chimneys," of which the Johnny Bull is the principal example in this region.

No sharp distinction exists between these various deposits. Lodes of flat dip may pass into bedding faults along weak strata, producing breccias which, when mineralized, are classed as blankets. The mineralization of such a breccia, particularly if the material be calcareous shale, is likely to be largely by metasomatic replacement, producing a deposit closely akin to those resulting from the simple replacement of limestone. Moreover, the ore bodies grouped under the second and third heads are always intimately connected with fissures or lodes which may or may not be themselves productive.

The greater part of the product of the district has come from the blankets. Some of the lodes have proved rich, but their value has invariably fallen below the limit of profitable working at a remarkably shallow depth, which generally bears a constant relation to some overlying blanket with which the lode or lodes connect. Some important

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ꟷOMIC GEOLOGY OF THE QUADRANGLE.

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DISTRIBUTION OF THE ORES.

In all probability more than half of the ore produced in the Rico district has come from Newman Hill. This name is applied to the slopes immediately south and east of Rico, constituting the western flank of Dolores Mountain. Newman Hill may be considered as bounded on the north by Silver Creek, on the west by the Dolores River, on the south by Deadwood Gulch, and on the east by the cliffs formed by the massive bed of limestone characteristic of the medial division of the Hermosa. On this slope, which is deeply covered with surface wash, are the Enterprise, Rico-Aspen, Newman, Union-Carbonate, and other mines, in which the ore occurred partly in lodes and partly in blankets. Of the latter the principal one is locally known as the Newman Hill or Enterprise "contact."

Also on the east side of the Dolores River, but north of Silver Creek, is Nigger Baby Hill, a spur of Telescope Mountain. This hill has produced ore since 1879. The ore occurs in oxidized form in lodes, which in their upper portions possess so flat a dip as to constitute essentially blanket deposits.

C. H. C. Hill lies immediately north of Nigger *Baby Hill. It is a landslide area, honeycombed* with workings from which much ore has been taken. The ore, largely oxidized, occurs in blankets, the continuity of which has been greatly broken by landslide movements.

From the three hills mentioned has come the greater part of the Rico ore. There are, however, several important outlying deposits. The most prominent of these is that of the Blackhawk mine, between Silver Creek and Allyn Gulch, ... the ore occurs oxidized in a lode and as mineralogical or commercial distinction, and are not necessarily of different age.

The principal minerals occurring as a direct result of the general processes of mineralization are as follows:

Pyrite.—This is by far the most abundant sulphide in the district. Associated with quartz and small amounts of chalcopyrite, sphalerite, and galena, it constitutes the practically worthless filling of most of the lodes. It is found in large blanket-like masses, free from gangue, in C. H. C. Hill. In similar masses, but usually in more solid condition, it is found as a replacement of limestone. This is the mode of its occurrence in the Blackhawk mine, where it is frequently associated with fluorite and grades by increase of chalcopyrite and galena into workable ore. Although commonly containing small quantities of silver and gold, the pyrite has hitherto proved too low in grade for successful treatment. Rickard records that the pyrite from the northwesterly lodes in the Enterprise mine usually afforded on assay from 4 to 8 ounces of silver and traces of gold. In the Gold Anchor prospect in Bull Basin a large body of pyrite was found which is said to have indicated, in single assays, as much as 90 ounces of gold per ton, but which as a whole did not pay the cost of extraction.

Galena.—This very important ore mineral occurs abundantly in the Enterprise blanket and in most of the bodies of unoxidized ore that have been *worked in the district. It is always argentiferous,* but apparently does not constitute rich ore unless accompanied by argentite, tetrahedrite (freibergite?), proustite, or polybasite, as is the case in the Newman Hill mines. On the other hand, it nowhere occurs in sufficiently large masses, unless possibly in the Atlantic Cable mine, to be workable for its lead alone. It presents no unusual peculiarities in this region and is, as elsewhere, nearly always accompanied by sphalerite.

Sphalerite.—Zinc blende is an abundant constitwhat are now known as the Atlantic Cable, Aztec, Phoenix, and Yellow Jacket claims. They were unsuccessful, and it was not until 1877 that active prospecting was resumed in the Pioneer district.

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Since 1895 the output of the Pioneer district has decreased. The large bodies of rich "contact" ore have been mined out, and many of the veins have been worked down to a depth at which the ore no longer pays for shipment. Masses of ore often proved to be curiously limited, owing to various conditions that are characteristic of the region and that will presently be described.

The decline in the price of silver has had a depressing effect on this as on other districts where this metal forms a large part of the output. But nearly all the important ore bodies formerly exploited were sufficiently rich to be workable to-day had they not been exhausted. In 1900 the only ore being shipped from the district was an occasional carload taken out by leasers working small areas of unexplored ground in the larger mines.

In 1902 practically all the important mines in the district were consolidated under the name of the United Rico Mines Company and although no material increase of production has yet resulted, the new company has devoted itself with considerable success to the development of the Atlantic no necessary connection with its true geological meaning, has unfortunately found its way into literature and has been so universally adopted by the miners that it is difficult to altogether avoid its use. Wherever employed, however, the word will be placed in quotation marks, indicating its true standing as miners' vernacular.

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The greater part of the product of the district has come from the blankets. Some of the lodes have proved rich, but their value has invariably fallen below the limit of profitable working at a remarkably shallow depth, which generally bears a constant relation to some overlying blanket with which the lode or lodes connect. Some important bodies of ore have also been formed by direct replacement of limestone.

The bulk of the ore has been found in the Carboniferous sedimentary series, particularly that portion of it known as the Hermosa formation. This is nearly equivalent to saying that most of the ore has come from the central portion of the district, in the heart of the dome-like uplift of the Rico Mountains.

The ores consist primarily of galena—often highly argentiferous and associated with rich silver-bearing minerals—sphalerite, and pyrite, several important outlying deposits. The most prominent of these is that of the Blackhawk mine, between Silver Creek and Allyn Gulch, where the ore occurs oxidized in a lode and as sulphide replacement deposits in massive limestone. Another example is the Puzzle mine, on Horse Creek, about three-fourths of a mile from its mouth, where the ore also occurred replacing limestone. The Johnny Bull mine on Johnny Bull Mountain, near the head of Horse Creek, has also produced some ore.

The entire basin of Horse Creek and the eastern slope of Expectation Mountain are dotted with prospects, many of which have produced small quantities of ore, but nearly all are now abandoned.

Another deposit of considerable interest and prospective value is that of the Atlantic Cable mine, on the north side of the town, in which galena, sphalerite, and other minerals occur as replacements of the Devonian limestone.

By reference to the geological map the preponderance of the important ore bodies occurring in the Hermosa, particularly in the lower and middle divisions, will be evident. Near the periphery of the dome, where the Permian, Triassic, and Jurassic sediments now constitute the surface, no large ore bodies have been found. The Johnny Bull, it is true, occurs in Dolores rocks, but the ore body, although at one time giving rise to considerable excitement, proved to be little more than a pocket.

MINERALOGY OF THE ORES.

The ores of the Rico district present few noteworthy or peculiar mineralogical features, and need receive but brief treatment under this head. They may be roughly divided into (1) pyritic ores, usually of very low grade, and (2) argentiferous galena ores, sometimes with rich silver minerals and often containing much sphalerite. The pyritic ores constitute the characteristic vein filling of most of the lodes and occur in many of the blankets and other deposits. The galena ores form the workable ore bodies, deposited under various favorable circumstances of concentration. The two kinds of ore are not capable of sharp able for its lead alone. It presents no unusual peculiarities in this region and is, as elsewhere, nearly always accompanied by sphalerite.

Sphalerite.—Zinc blende is an abundant constituent of the rich ores of Newman Hill, which sometimes contain over 15 per cent of zinc. Its common associates in these ores are galena, chalcopyrite, rhodochrosite, and quartz, and it occurs both in the northeasterly lodes and in the blanket. It is also found in massive granular form, associated with a little chalcopyrite, galena, and fluorite, in the Blackhawk mine, where it makes up a considerable part of the large replacement bodies in limestone. In the Atlantic Cable claim it occurs in coarsely crystalline nodular masses, associated with chlorite, specularite, chalcopyrite, and galena, in limestone. This sphalerite is dark brown, while that in the Newman Hill veins is usually rosin colored. It is also abundant in the Sambo mine and in the Bancroft and Lily D. prospects, associated with galena. The occurrence of sphalerite has until recently been purely an objectionable feature in the ores, owing to the penalty attached by the smelters to ores containing over 10 per cent of zinc. But in 1900 experiments were begun to determine the feasibility of working some of the sphalerite ores for zinc. At the present time zinc ore is extracted in commercial quantities from the Atlantic Cable by the United Rico Mines Company and treated in a small stamp mill. The galena is saved on vanners and the sphalerite concentrated by a magnetic separator. Some shipments have been made, but the plant is essentially experimental.

Chalcopyrite.—This mineral is not very abundant in the Rico district, although nearly always present with galena and sphalerite in the workable ores. Associated with pyrite, fluorite, and some finely granular galena and sphalerite, it formed some of the best ore in the Blackhawk replacement bodies, where it often occurred in fine concentric or irregularly curved, narrow bands. It is present in small quantity in the blanket and lode ores of Newman Hill, in the Silver Swan, Aztec, and Atlantic Cable prospects, and in many other lodes and blankets throughout the district.

Tetrahedrite.—Gray copper ore occurs in the

COLUMNAR SECTION

GENERALIZED SECTION FOR THE RICO QUADRANGLE.
SCALE: 1 INCH = 400 FEET.

System.	Series.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Formations.
CRETACEOUS	UPPER CRETACEOUS	Mancos shale.	Km		1000+	Soft, dark gray, or almost black, carbonaceous clay shale containing thin lenses or concre impure limestone. Embraces the Colorado group and a portion of the Pierre division Montana. Fossils occur more or less abundantly at several horizons.
		Dakota sandstone.	Kd		100-250	Gray or rusty brown quartzose sandstone or quartzite with a variable conglomerate, con small chert pebbles at or near the base. Carbonaceous shale partings occur at several l and coal of poor quality is locally present. Indistinct fossil leaves occur sparingly.
JURASSIC		McElmo formation.	Jmc		400-1000	A complex of alternating friable, fine-grained, yellowish or grayish sandstones and shale sandstones are seldom more than 20 feet thick. They often include flakes of grayish shale. The shales are chiefly green in color, but may be pink, dark red, or chocolate Some shale layers are sandy and others highly calcareous. No fossils have been found McElmo strata.
		La Plata sandstone.	Jlp		250-500	Consists principally of two massive, friable, white sandstone beds, with a narrow band o limestone or calcareous shale between them. The sandstones are quartzose, of even gra tinctly cross bedded, and form massive cliffs where exposed. The limestone or calcareou is locally brecciated or recemented. No determinable fossils have been found.
		UNCONFORMITY				
TRIASSIC?		Dolores formation.	Ȓd		400	Sandy marl and fine-grained sandstone and shale of bright-red color with fine limesto glomerate near the base, in which are found teeth of a crocodile (*Belodon*) and of a meg roid dinosaur, with a rare gasteropod shell similar to *viviparus*, indicating the Triassic the formation,
		UNCONFORMITY				
CARBONIFEROUS	PERMIAN?	Cutler formation.	Cc		1600	A complex of bright-red sandstones and lighter red or pinkish grits and conglomerates alter with sandy shales and earthy or sandy limestones of varying shades of red.
	PENNSYLVANIAN	Rico formation.	Cr		300	Dark reddish-brown sandstone and pink grit, with intercalated greenish or reddish sha sandy, fossiliferous limestone.
		Hermosa formation.	Ch		1800-2000	A series of grits, sandstones, shales, and limestones of varying distribution and develop Grit and sandstone in massive beds predominate in the middle and upper parts of the s the lower portion consisting of thinner bedded sandstone, shale, and limestone layers. N ous invertebrate fossils occur in shale and limestone.

McElmo formation.	Jme	400-1000	A complex of alternating friable, fine-grained, yellowish or grayish sandstones and shales. The sandstones are seldom more than 20 feet thick. They often include flakes of grayish clay or shale. The shales are chiefly green in color, but may be pink, dark red, or chocolate brown. Some shale layers are sandy and others highly calcareous. No fossils have been found in the McElmo strata.
La Plata sandstone.	Jlp	250-500	Consists principally of two massive, friable, white sandstone beds, with a narrow band of dark limestone or calcareous shale between them. The sandstones are quartzose, of even grain, distinctly cross bedded, and form massive cliffs where exposed. The limestone or calcareous shale is locally brecciated or recemented. No determinable fossils have been found.
UNCONFORMITY			
Dolores formation.	Td	400	Sandy marl and fine grained sandstone and shale of bright-red color with fine limestone conglomerate near the base, in which are found teeth of a crocodile (*Belodon*) and of a megalosauroid dinosaur, with a rare gasteropod shell similar to *viviparus*, indicating the Triassic age of the formation.
UNCONFORMITY			
Cutler formation.	Cc	1600	A complex of bright-red sandstones and lighter red or pinkish grits and conglomerates alternating with sandy shales and earthy or sandy limestones of varying shades of red.
Rico formation.	Cr	300	Dark reddish-brown sandstone and pink grit, with intercalated greenish or reddish shale and sandy, fossiliferous limestone.
Hermosa formation.	Ch	1800-2000	A series of grits, sandstones, shales, and limestones of varying distribution and development. Grit and sandstone in massive beds predominate in the middle and upper parts of the section, the lower portion consisting of thinner bedded sandstone, shale, and limestone layers. Numerous invertebrate fossils occur in shale and limestone.
UNCONFORMITY			
Ouray limestone.	DCo	100-300	Dull yellow to buff, compact limestone, lower third shaly with thin quartzites. Abundant fossils indicate Devonian age of lower two-thirds and Mississippian age of upper part.
UNCONFORMITY			
Ignacio quartzite.	Ci	0-200	Quartzite, massive and conglomeratic in lower part, thin bedded with shale and sandy partings in medial zone, succeeded by more massive quartzite. Light gray, pink, or yellow predominates. One shell, *obolus* sp. ?, has been found near the middle of the formation.
UNCONFORMITY			
Uncompahgre formation.	Au		White or smoky quartzite and dark slate, mainly massive, but in a few places alternating in thinner layers. No fossils have been found.

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ALGON

WHITMAN CROSS,
ARTHUR C. SPENCER,
Geologists.

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be determined by observing their positions. This relationship holds except in regions of intense disturbance; in such regions sometimes the beds have been reversed, and it is often difficult to determine their relative ages from their positions; then *fossils*, or the remains and imprints of plants and animals, indicate which of two or more formations is the oldest.

Stratified rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land into lakes or seas, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. When two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains found in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it.

Similarly, the time at which metamorphic rocks were formed from the original masses is sometimes shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not of their metamorphism.

Colors and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern, and is labeled by a special letter symbol.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent; Pleistocene	Q	Brownish-yellow.
	Tertiary	Pliocene; Miocene; Oligocene; Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		Ћ	Peacock-blue.
Paleozoic	Carboniferous	Permian; Pennsylvanian; Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red purple.
		Saratogan		

planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin.

The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system. The symbols by which formations are labeled consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters. The names of the systems and recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

SURFACE FORMS.

Hills and valleys and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; sea cliffs are made by the eroding action of waves, and sand spits are built up by waves. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are produced in the making of deposits and are inseparably connected with them. The hooked spit, shown in fig. 1, is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion, and these are, in origin, independent of the associated material. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterwards partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain*. If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—This map shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any colored pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

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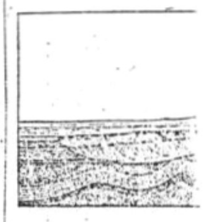

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